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Prepared by

I. J. Kim

Analysis and Experiment Support Section
TRW Systems Group



Prepared for
Mission Planning and Analysis Division
National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas

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Prepared by *I. J. Kim* Approved by *E. D. Stuckie*
I. J. Kim E. D. Stuckie, Manager
Analysis and Experiment Software Technology
Support Section Applications Department

Approved by *J. B. Moore* Approved by *E. L. Barnett*
J. B. Moore, Manager E. L. Barnett
JSC/TRW Task AA-53 Assistant Project Manager
Mission Trajectory Control
Program

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ABSTRACT

This report is submitted to NASA/JSC by TRW Systems Group in accordance with JSC/TRW Task AA-53 of the Mission Trajectory Control Program, Contract NAS 9-12330.

This document describes the programming techniques used to implement the equations of the Apollo Photograph Evaluation (APE) Program on the UNIVAC 1108 computer and contains detailed descriptions of the program structure, a User's Guide section to provide the necessary information for proper operation of the program, and information for the assessment of the program's adaptability to future problems.

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1. INTRODUCTION

APOLLO PHOTOGRAPH EVALUATION (APE) PROGRAMMING MANUAL

Prepared by:

I. J. Kim

Analysis and Experiment Support Section
TRW Systems Group

1. INTRODUCTION

This programming manual presents the information necessary for the use and assessment of the Apollo Photograph Evaluation (APE) computer program in its final form (Version 9). The description of an earlier version, which is restricted in application to lunar orbiter photograph evaluation data generation, can be found in Reference 1.

APE is a moon-centered, mixed precision, UNIVAC 1108 computer program designed and constructed for the generation of initial postflight estimates of location, orientation, and lighting of photographs taken with Apollo CSM-mounted cameras. The program, developed by TRW Systems Group for the Johnson Space Center at Houston, Texas, is written in FORTRAN V for use on the EXEC II system.

The general applications of APE are discussed in Section 2.1. The special applications of APE for the prediction of stellar camera star patterns and for the production of data in support of certain nonphotographic Apollo experiments are discussed in Section 2.2. Section 3 presents a detailed description of the program structure. Section 4 provides all the information required for proper use of the program. Descriptions of APE special application alter decks are presented in the Appendix.

2. PROGRAM DESCRIPTION

2. PROGRAM DESCRIPTION

2.1 GENERAL APPLICATION

The general application of APE is to generate support data for the evaluation of photographic data from any of the following Apollo CSM cameras: sextant, SIM-bay mapping, SIM-bay panoramic, and window mounted. For this application, APE produces a standard output tape and an on-line printout of the photograph evaluation parameters listed in Table 2-1. The format of the standard APE output tape is presented in Table 4-15. The on-line output is assigned to FORTRAN unit 6, while the tape output is assigned to FORTRAN unit 4.

Table 2-1. Photographic Evaluation Parameter - General Application

<u>Output Parameter</u>	<u>Description</u>
Title and page	Title and page (or photo frame) number.
GMT	Sidereal time of film exposure (year, month, day, hour, minute, second) - (UT1 - USNO).
CTE	Central clock time of film exposure which is recorded on the film (hour, minute, second).
1950 state vector	Mean of 1950 moon centered, inertial, cartesian coordinates of the spacecraft position (km) and velocity (km/sec).
Selenographic state vector	Selenographic, instantaneous inertial cartesian coordinates of vehicle position (km) and velocity (km/sec).
Nadir point (longitude/latitude)	Intersection with the mean lunar surface of the vector from the moon's center of mass to the spacecraft.
Camera axis intersect (longitude/latitude)	Position of principal intersection point; intersection of camera optical axis direction with mean lunar surface.
Spacecraft radius	Vector from moon center of mass to spacecraft.
Spacecraft altitude	Height of spacecraft above mean lunar surface.

Table 2-1. Photographic Evaluation Parameters - General Application (Continued)

<u>Output Parameter</u>	<u>Description</u>
Scale factor	Proportionality constant relating dimensions on the film to dimensions on the mean lunar surface.
Azimuth of velocity vector	Angle, measured positive clockwise in the local horizontal plane at nadir, between north and the projection of the vehicle velocity vector onto the local horizontal plane.
Mean altitude rate	Rate of change in spacecraft altitude above the mean lunar surface.
Horizontal velocity	Component of spacecraft velocity parallel to the lunar local horizontal plane at the nadir point.
Tilt azimuth	Angle, measured positive clockwise in the local horizontal plane at the principal intersection point, between north and the projection of a vector along the camera optical axis onto that local horizontal plane.
Tilt	Angle between the camera optical axis direction and the lunar local vertical at the nadir point.
Sun elevation at principal ground point	Angle between the vector from the sun to the principal intersection point and the lunar local horizontal plane at the point.
Sun azimuth at principal ground point	Angle, measured positive clockwise in the lunar local horizontal plane, from north to the projection of the vector from the sun to the principal intersection point onto that plane.
Subsolar point (longitude/latitude)	Intersection with the mean lunar surface of a vector from the moon's center of mass to the sun's center.
Alpha	Angle between the camera optical axis and the projection of the lunar local vertical at the principal intersection point onto the plane of the phase angle (measure of surface tilt toward or away from the sun).

Table 2-1. Photographic Evaluation Parameters - General Application (Continued)

<u>Output Parameter</u>	<u>Description</u>
Swing	Angle between the camera Y-axis and the projection of the line between the vehicle nadir and principal intersection point onto the camera X-Y plane.
Emission angle	Angle between the camera optical axis and the lunar local vertical at the principal intersection point.
Phase angle	Angle between the camera optical axis and the vector from the sun to the principal intersection point.
North deviation angle	Angle, measured positive clockwise in the camera X-Y plane, from the camera X-axis to lunar north.
Phi, Kappa, Omega	Angles which rotate the camera axes coordinate system into the nadir point centered lunar local horizontal system, where: <ul style="list-style-type: none"> - Primary right-handed rotation about the camera Y-axis - Secondary right-handed rotation about the intermediate X-axis - Final right-handed rotation about the local vertical (local horizontal Z-axis)
X-tilt	(lateral tilt) Angle from the local horizontal plane at the nadir point to the camera Y-axis.
Y-tilt	(longitudinal tilt) Angle from the local horizontal plane at the nadir point to the camera X-axis.
Heading	Angle, measured positive clockwise in the lunar horizontal plane at the nadir point, from north to the projection of the camera X-axis onto that plane.
Laser slant range	Telemetered laser altimeter readout.
Spacecraft altitude (laser)	Vertical component of laser altimeter slant range based on the assumption that the laser altimeter was aligned along the three-inch mapping camera optical axis.

Table 2-1. Photographic Evaluation Parameters - General Applications (Continued)

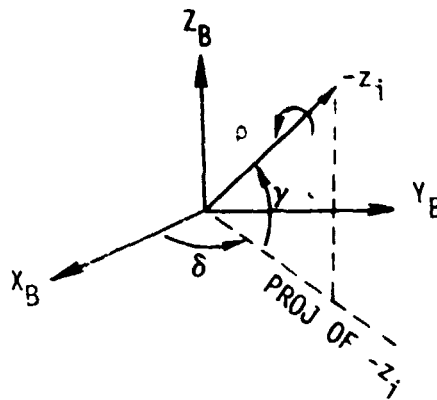
<u>Output Parameter</u>	<u>Description</u>
Selenographic direction cosines	Direction definition of vector from the spacecraft to the principal intersection point in the instantaneous inertial selenographic coordinate system.
Coordinate transformation matrices	Selenocentric coordinate system to camera axes coordinate system and local horizontal coordinate system to the camera axes coordinate system.
Photograph footprint	Latitudes and longitudes of field of view corner point projections onto the lunar surface (full field of view only for mapping camera, full field of view and inner field of view for panoramic camera).
Sigmas	First order uncertainties in selected camera aiming parameters arising from uncertainties in camera mounting angles, vehicle attitude measurements and film exposure times.

2.1.1 Generalized Fixed Camera

This model, developed for consideration of any of the early Apollo window-mounted cameras, is the basic APE camera model. This simple, three-degree-of-freedom camera model, with the camera axes oriented as shown in Figure 2-1, provides the program logic for essentially all APE geometric definitions. This same basic logic is used for the APE definition of instrument-vehicle-target geometry, and all of its applications after the instrument mounting and control parameters are converted to generalized APE instrument mounting angle equivalents for definition of the spacecraft body axes to instrument axes transformation. This redefinition is by way of the following coordinate transformation matrix:

$$[BD2CM] = \begin{bmatrix} \cos\rho & \sin\rho & 0 \\ -\sin\rho & \cos\rho & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \sin\gamma & 0 & \cos\gamma \\ 0 & 1 & 0 \\ -\cos\gamma & 0 & \sin\gamma \end{bmatrix} \begin{bmatrix} \cos\delta & \sin\delta & 0 \\ -\sin\delta & \cos\delta & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (1)$$

where: ρ (RHO), γ (DOQ) and δ (DOR) are the generalized APE camera or instrument mounting angles.



ρ , γ and δ = camera mounting angles

Figure 2-1. Generalized Camera Axes Coordinate System

Regardless of the camera or instrument under consideration by APE, the above transformation matrix is applied after the parameters of that matrix have been properly defined in terms of the mounting and control angles of the specific instrument or camera being considered. These definitions are according to the following formulae which arise from equating the vehicle axes to instrument axes coordinate transformation [M] to the above [BD2CM]:

$$\rho = \tan^{-1} \left(\frac{-M_{23}}{M_{13}} \right)$$

$$\gamma = \sin^{-1} M_{33} = \tan^{-1} \left(\frac{\cos \rho M_{33}}{M_{13}} \right)$$

$$\delta = \tan^{-1} \left(\frac{-M_{32}}{-M_{31}} \right)$$

Generally speaking, the treatment of any instrument, other than a simple fixed mounted camera without precise shutter timing definition, requires additional logic to reflect special features and requirements.

The additions required for consideration of the various Apollo cameras and instruments are discussed in the following sections devoted to those particular cameras and instruments.

2.1.2 Sextant Camera (ISHFTR = 2)

The Apollo sextant camera, used only on Apollo 12 and Apollo 14, differs from all other Apollo cameras in that it has time varying sextant shaft angle (β') and sextant trunnion angle (θ'). The processing of data from this camera by APE requires either that histories of these angles be input by tape or that their values at all computation times be input on cards (Input 2). When input by tape, these histories are included with the CSM attitude data (pre-Apollo 15 gimbal tape format (Table 4-12)).

When operating on sextant camera data, APE first converts the camera mounting angles γ' , β' , θ' (Table 2-2), whose values are either provided by card input or are interpolated from tape input histories, to the equivalent general camera mounting angles ρ , γ , δ by way of conversion formulae. These equivalents are then employed in the construction of the BD2CM matrix for use in the nominal program flow (Figure 2-2).

Table 2-2. Card Input Sextant Mounting Angles

Namelist Input (degrees)	Internal Variable (radians)
β' : Sextant shaft angle = CSHAFT (real)	SXSHFT
θ' : Sextant trunnion angle = CTRUN (real)	SXTRUN
γ' : Constant position angle = SXLAMB (double precision)	DOP

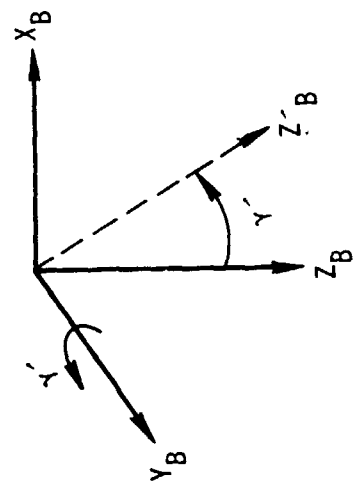
Referring to Figure 2-2, the transformation (BD2CAM) is defined as follows:

$$[BD2CM] = \begin{bmatrix} -\cos\theta' & 0 & \sin\theta' \\ 0 & 1 & 0 \\ -\sin\theta' & 0 & -\cos\theta' \end{bmatrix} \begin{bmatrix} \cos\beta' & \sin\beta' & 0 \\ -\sin\beta' & \cos\beta' & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\gamma' & 0 & -\sin\gamma' \\ 0 & 1 & 0 \\ \sin\gamma' & 0 & \cos\gamma' \end{bmatrix} \quad (2)$$

In the program, the elements of BD2CM are computed by equation 1 using the converted ρ , γ , and δ (equation 3).

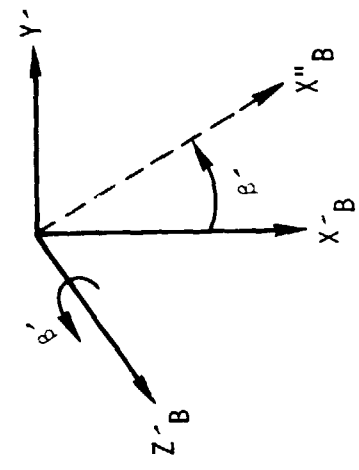
$$\left. \begin{aligned} \rho &= \tan^{-1} \left(\frac{-\sin\theta}{\cos\theta \cos\beta' + \sin\theta' \cot\gamma'} \right) \\ \gamma &= \sin^{-1} (\sin\theta' \cos\beta' \sin\gamma' - \cos\theta' \cos\gamma') \\ \delta &= \tan^{-1} \left(\frac{\sin\theta'}{\cos\beta' \cos\gamma' + \sin\gamma' \cot\gamma'} \right) \end{aligned} \right\} \quad (3)$$

Primary - γ' rotation
about Y_B Body-axis



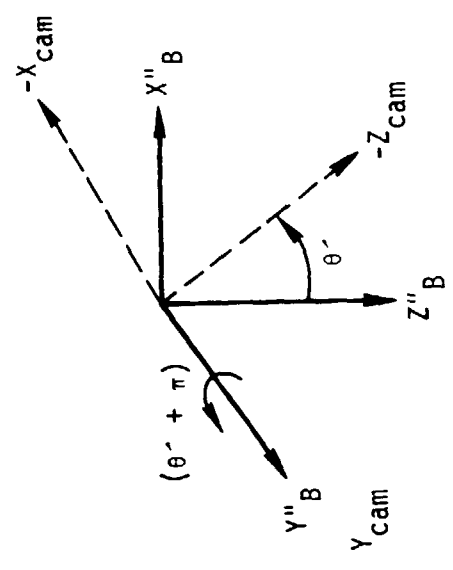
where
 $\gamma' =$ Constant Position Angle

Secondary - β' rotation
about Z'_B Body-axis



where
 $\beta' =$ Shaft Angle

Tertiary - $(\theta' + \pi)$ rotation
about Y''_B Body-axis



where
 $\theta' =$ Trunnion Angle

Figure 2-2. Sextant Mounting Angles

2.1.3 SIM-Bay Mapping Camera

The SIM-bay mapping camera was used on Apollo flights 15, 16, and 17 and synchronized with the Apollo stellar camera and laser altimeter. The APE treatment of this camera requires a card input of photo frame number, onboard clock film exposure time and where available, laser altimeter slant range for each computational point. These cards, in the format shown in Table 4-5, are input as a chronologically ordered card deck which follows the control card input (\$INPUT1). The input deck must be ordered, in position and number, to exactly match the vectors appearing on the input trajectory tape. A card containing an X in column 5 must be included in this deck in the position which corresponds to every vector appearing on the input trajectory tape which does not correspond to a film exposure time.

This application also requires that appropriate values for the mapping camera to stellar camera interlock angles θ_X , θ_Y , and θ_Z be set by a data statement at sequence number 178 of subroutine APECOM as I1, I2, and I3, respectively. These angles must be input in radians.

The mapping camera optical axis (-Z cam) lies along the SIM-bay center-line which is inclined 37.75° to the Z-body axis as shown in Figure 2-3.

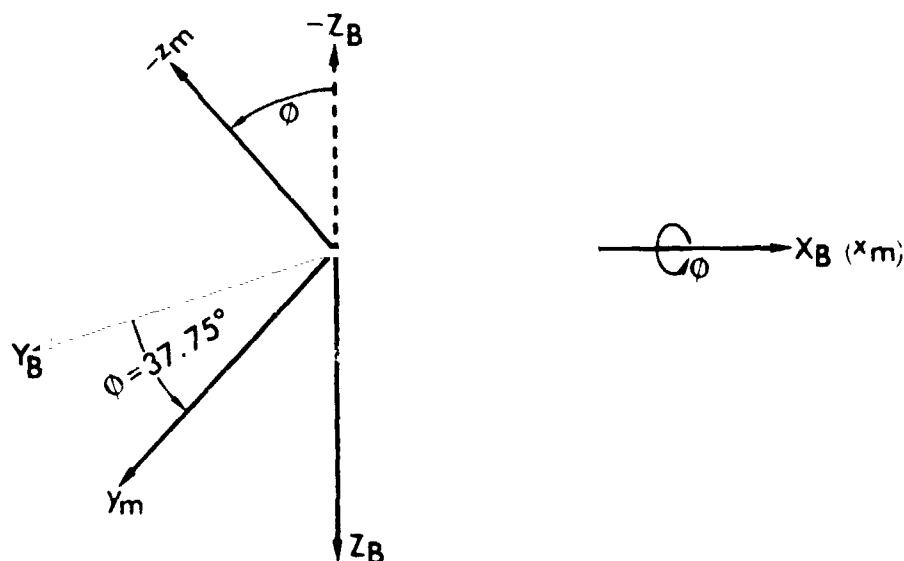


Figure 2-3. SIM-Bay 3-Inch Mapping Camera Axes Coordinate System

The APE program first converts the camera mounting to the APE generalized camera mounting parameters ρ (RHO), γ (DOQ), and δ (DOR) as follows:

$$\rho = \frac{3\pi}{2}, \quad \gamma = \frac{\pi}{2} - \phi, \quad \delta = \frac{\pi}{2}$$

where: ϕ = Mapping camera mounting angle (37.75°)

The mapping camera computations are then carried out by way of the nominal APE flow modified to:

1. Transport photo frame number, onboard clock film exposure time and laser altimeter slant range from card to output
2. Compute vertical component of laser altimeter slant range for output
3. Compute right ascension and declination of stellar camera aiming axis for output

The APE outputs for this camera are unique in that they include, in addition to the standard set of parameters, laser altitude, laser slant range, and stellar camera aiming direction (right ascension and declination).

2.1.4 Apollo Panoramic Camera (ISHFTR = 4)

The Apollo panoramic camera was used on Apollo flights 15, 16, and 17. This camera has two operational modes: "stereo" and "mono." In the "stereo" mode, the camera oscillated between $+12.5^\circ$ forward and -12.5° aft of the SIM-bay center line (Figure 2-4) at a nominal frequency of 10 cpm but which was varied according to altitude range. In the "mono" mode the panoramic camera was held in a fixed position with its optical axis directed along the SIM-bay center line in a position identical with the mapping camera (Figure 2-3). The APE treatment of this camera requires a card input of photo frame number and onboard clock time of film exposure for each computational point. These cards, in the format shown in Table 4-6 are input as a chronologically ordered card deck which follows the control card input (RINPUT1). The deck must be ordered to exactly match, in position and number, the vectors appearing on the input trajectory tape. A card containing an X in column 2 must be included in this card deck in the position corresponding to every

vector appearing on the input trajectory tape which does not correspond to a film exposure time.

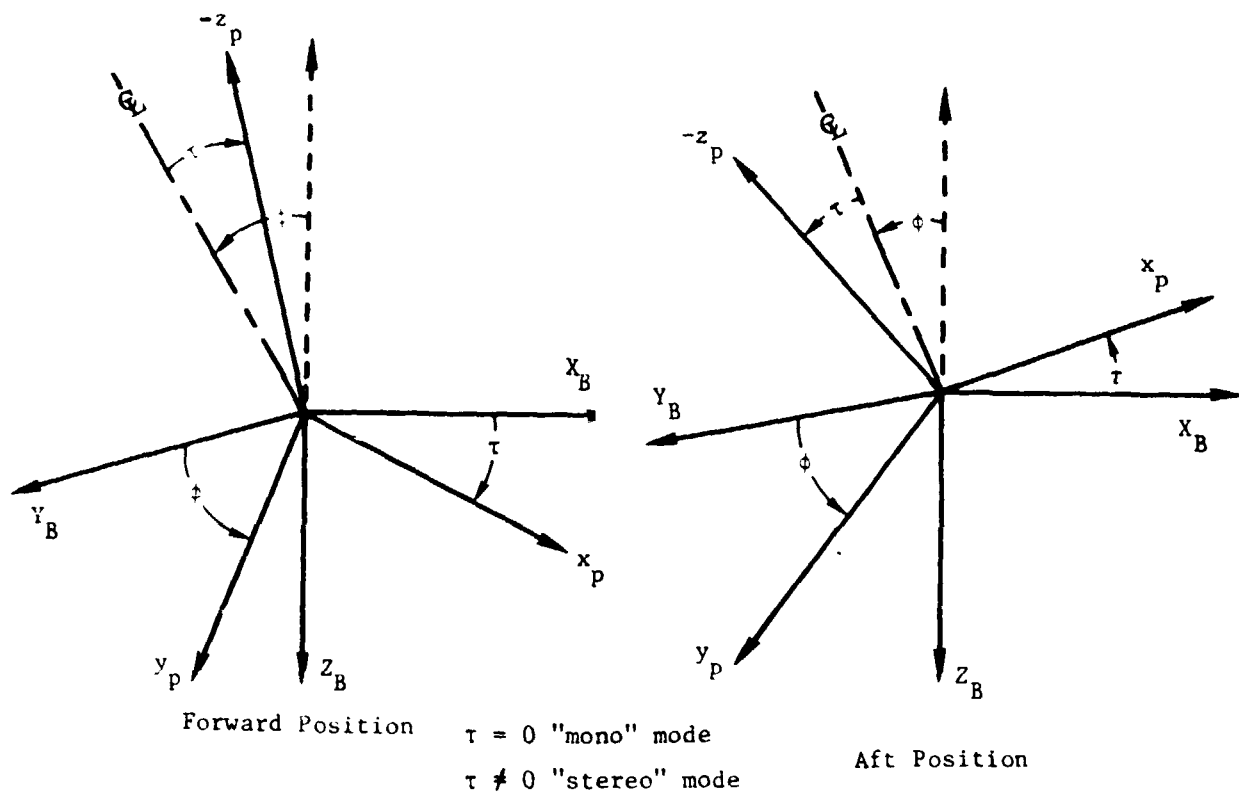


Figure 2-4. Panoramic Camera Axes Coordinate System

The first character of the card input photo frame number designates camera mode and camera aiming direction. This designation, the input for the APE parameter KOPAN, determines the computational flow. If the designator is V, then the "mono" mode flow is followed; otherwise, the "stereo" mode flow is followed.

When in the "mono" mode (KOPAN = V), the computational flow is that of the SIM-bay mapping camera (ISHFTR = 2) modified to omit the computations of vertical component of laser altimeter slant range and of the stellar camera aiming direction.

When in the "stereo" mode (KOPAN = A or F), APE first converts the panoramic camera mounting angles $\phi = 37.75$ (mounting angle) and τ (excursion angle) to the equivalent generalized APE camera mounting angles ρ (RHO), γ (DOQ) and δ (DOR) as follows:

$$\rho = \tan^{-1} \left[\frac{-\sin \phi}{-\sin (K\tau) \cos \phi} \right]$$

$$\gamma = \sin^{-1} \left[\cos (K\tau) \cos \phi \right]$$

$$\delta = \tan^{-1} \left[\frac{\cos (K\tau) \sin \phi}{-\sin (K\tau)} \right]$$

where: $\phi = 37.75^\circ$ (nominal)

$\tau = 12.5^\circ$ (nominal)

K = Switching constant

= -1 when KOPAN = F

= +1 when KOPAN = A

The outputs for this camera are unique in that they include an additional set of field of view corner point locations (inner field of view). Stellar camera aiming axis right ascension and declination and laser altimeter and slant range are omitted from the output.

See Appendix A.1 for a description of the alters required for the operation of this program option.

2.2 SPECIAL APPLICATIONS

Special applications of the APE program will produce predictions of star patterns within the Apollo stellar camera field of view at specified film exposure times or support data for the Apollo IR scanner and lunar sounder experiments. These applications all deviate from the generalized APE applications in some combination of input, computational, or output requirements.

2.2.1 Apollo Stellar Camera (ISHFTR = 3)

This special application of APE locates and computes the diapositive coordinates of the brightest BOSS numbered star in each of 16 equal sectors of the Apollo stellar camera field of view at specified film exposures times. This, a time consuming application, was used to establish one or two star patterns for each Apollo stellar camera photographic sequence.

For this application, APE first defines the generalized APE camera mounting angles ρ , γ , and δ in terms of the SIM-bay mapping camera mounting angle (ϕ) and the map to stellar camera interlock angles θ_X , θ_Y , and θ_Z . These interlock angles are input to APE by way of a data statement at sequence number 178 of subroutine APECOM, where these angles are defined in radians as I1, I2, and I3, respectively. Following this definition of ρ , γ , and δ , the APE computational flow is identical with that for the SIM-bay mapping camera through the definition of the stellar camera aiming axis direction. At that point the calculations deviate to a program overlay for access to the star catalog search subroutine STARRD. The overlayed program structure is used to access a maximum amount of core for the bi-level star catalog search to increase the computational speed.

In the first level of the STARRD star catalog search, APE transfers all stars within APE computed ranges of mean of 1950 right ascension and declination from the input Apollo photo evaluation star catalog tape to computer core. In its second level of the STARRD search, APE selects from its stored stars the brightest one in each of 16 equal sectors of the stellar camera field of view at film exposure time. These are then on-line plotted, using APE computed stellar camera diapositive coordinates. This plot is followed in the output by a tabulation of the plotted stars; the star identification (SAO and BOSS number), the star diapositive coordinates, and brightness.

This application requires the input of an additional tape on unit X which is the Apollo Photograph Evaluation (APE) star catalog. This catalog, an extraction from the June 1967 SAO star catalog binary tapes, was prepared by TRW Systems Group and contains data only for those stars which have a photographic brightness of six or brighter and which have been assigned a BOSS catalog number. The data for each star, presented in the format described in Table 4-14, include SAO and BOSS catalog identification numbers, along with selected parameters that enter the APE computations.

Depending on the composition and arrangement of the APE input deck, star pattern predictions for any number of film exposures for a given Apollo stellar camera photographic sequence can be obtained, either isolated from or in conjunction with, the APE processing of the companion SIM-bay mapping camera data, with a single multi-execution of the program. The input deck must contain, for each star pattern requested, a complete \$INPUT1, stellar

camera card deck, preceded by a title card and followed by the map camera data card corresponding to the film exposure of the request and then by another title card. Each of these \$INPUT1 decks must contain the following inputs:

ISHFTR = 3

ISSEQI = Corresponding map camera photograph number

ISSEQF = Number beyond final photograph of the sequence

ISHFT = -5 (all except for the final case)

When the APE application is for a series of star pattern predictions, the required \$INPUT1 card decks must be chronologically ordered with no overlap of the intervals defined by the input star and stop times. Processing of the companion SIM-bay mapping camera data can be accomplished in the same multi-execution of APE by including its \$INPUT1 card deck as the final input deck.

2.2.2 Infrared Scanning Radiometer (S-171)

This special APE application produces support data for the Apollo infrared scanning radiometer experiment used during Apollo 17 flight. For this special application of APE, no additional card inputs are required, but the input trajectory tape must be the nonstandard HOPE special format 3 tape which contains, in addition to the standard APE input trajectory synchronized with the IR radiometer scan center crossings, the instantaneous IR scanner radiometer shaft rotation rate, ω , in radians/second at each trajectory time point T_{ci} . The rotation rates are double precision words added as DUM82(44), the 44th double precision word of each format 3 trajectory data record. The nonstandard format 3 trajectory tape can be prepared by the HPEINT program (see Reference 2).

The IR scanner mounting angles are set in the APE program as $RHO = \rho = 270.0$ degrees, $DOQ = \gamma = (90.0 - \phi)$ degrees, and $DOR = \delta = 90.0$ degrees; where the $\phi = PHIIRS$ should be input through the namelist/INPUT1/ input if ϕ is not zero. The SIM-bay Infrared Scanning Radiometer roll position angle, $PHIIRS' = \phi$, is 40.416667 degrees for Apollo 17. Geometrically, this angle is the same as the SIM-bay mapping camera mounting angle (Figure 2-3), differing only in magnitude.

This special application of APE deviates from the generalized APE program flow only in the compositions and formats of the online and tape outputs. The online outputs is a truncation of the standard APE output, with outputs for each computational point restricted to computational point number (frame number), computational time (CTE in hours, minutes, and seconds and GMT in years, months, days, hours, minutes, and seconds), spacecraft state vector (km and km/sec) as defined in both the selenographic and the mean of 1950 moon centered inertial coordinate systems. The output is composed of three parts, a single leading title record, a variable number of data records, and a concluding flag record. The formats of the title record and the flag record are the same as that of HOPE trajectory tape (format 3) or APE standard D-output tape. The format of the data record is defined in such a way that each physical record contains nine logical records and each logical record consists of 28 single precision words as shown in Table 4-16.

2.2.3 Lunar Sounder

This special application of APE is for the production of synchronized spacecraft state vector and attitude data for support of the Apollo Lunar Sounder experiment. With the exception of the program alter deck specified in Appendix A.2, the inputs required are identical with the \$INPUT for the SIM-bay mapping camera. For this application, data cards are not required. The only deviation from the generalized APE program flow is in the online print and tape outputs. The online print for each computational point is restricted to computational time (CTE and GMT), spacecraft state vector (mean of 1950 and selenographic), nadir point position (latitude and longitude), and spacecraft gimbal angle values. These same parameters, excluding CTE, are output to two tapes assigned to units E and F. The output to the E tape is formatted for subsequent translation to a 9-track EBCDIC tape for use as input to an IBM 360 computer program. The output to the F tape is unformatted binary. Both output tapes are 7 track. Tape outputs are as defined in Tables 4-17 and 4-18.

3. PROGRAM STRUCTURE

3. PROGRAM STRUCTURE

The APE main program, APEVAL, can be executed only by calling the MAP (Memory Allocation Processor) T1. It specifies program partitioning and core allocation. APEVAL allocates core to the program overlay only when necessary; otherwise, its core allocation is restricted to APECOM and its supporting subroutines. The APEVAL flow is shown in Figure 3-1.

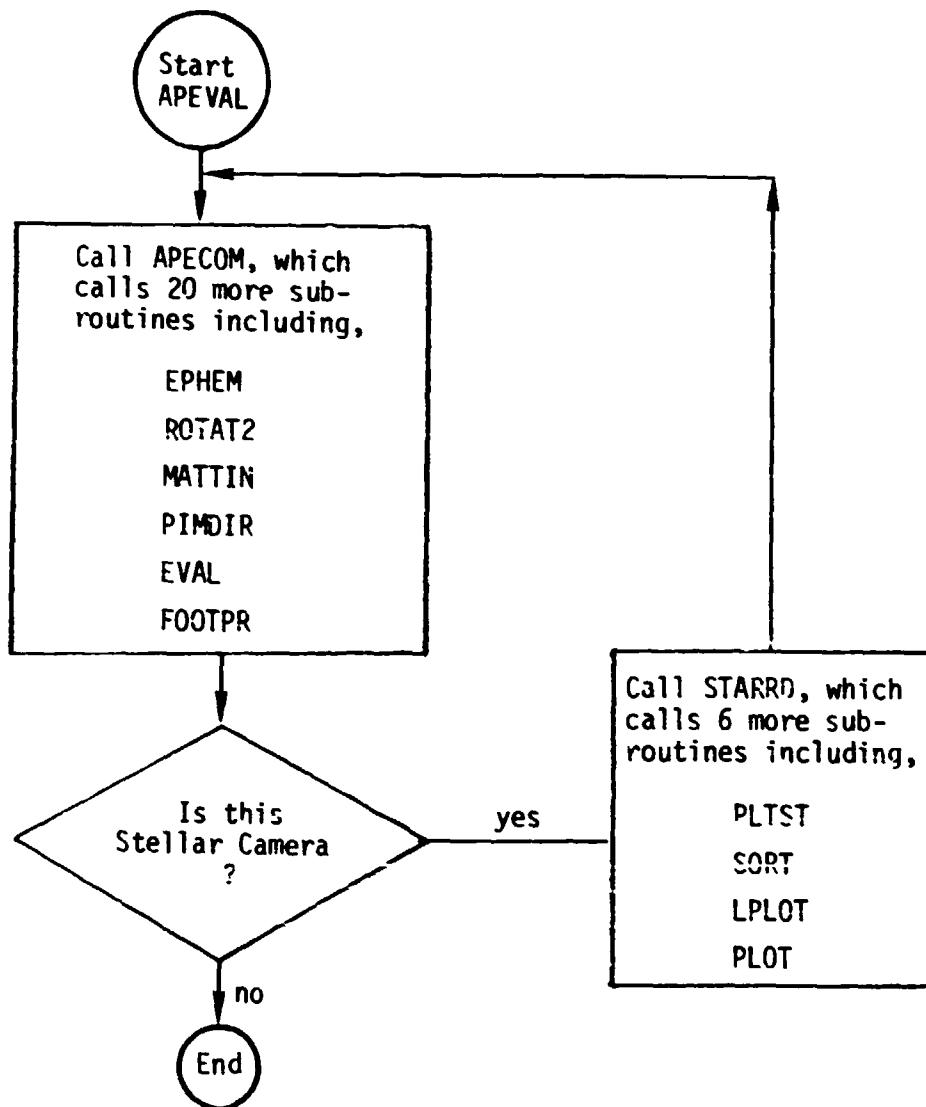


Figure 3-1. APEVAL Program Flow

3.1 OVERLAY STRUCTURE

The use of APE for the Apollo stellar camera requires a program overlay structure. This is due to the unusually high core requirements of the star catalog search, star coordinate definition manipulations, and star pattern plot construction.

With these high core demands, any attempt at single line allocation will result in core memory overflow.

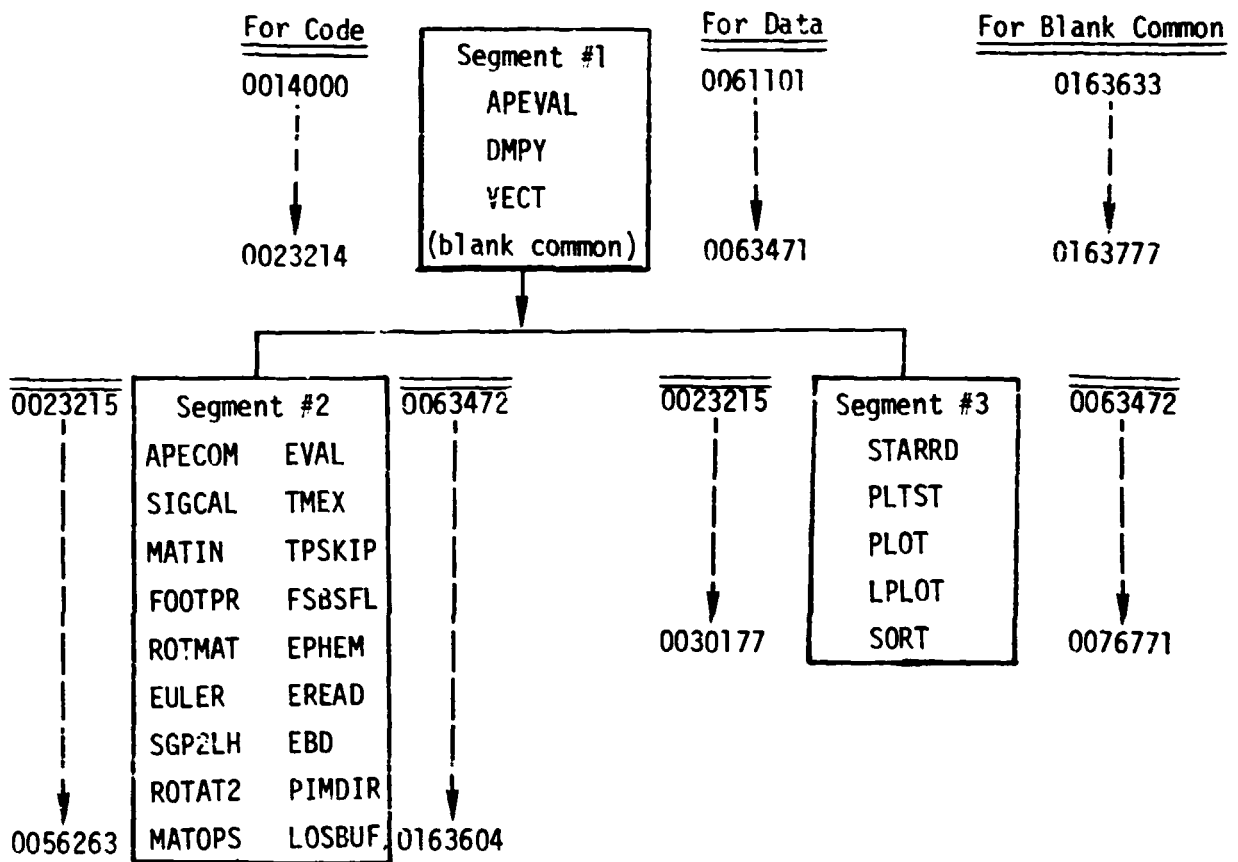


Figure 3-2. Overlay Structure for APE

APE is partitioned as shown in Figure 3-2. The first segment contains APEVAL, DMPY, and VECT. The core location assignments in octal for this segment are 0014000 to 0023214 for the code, from 0061101 to 0063471 for the data, and from 0163633 to 0163777 for the blank common.

The second segment contains APECOM and 17 other subroutines. The core location assignments for this segment are from 0023215 to 0056263 for the code and from 0063472 to 00163604 for the data.

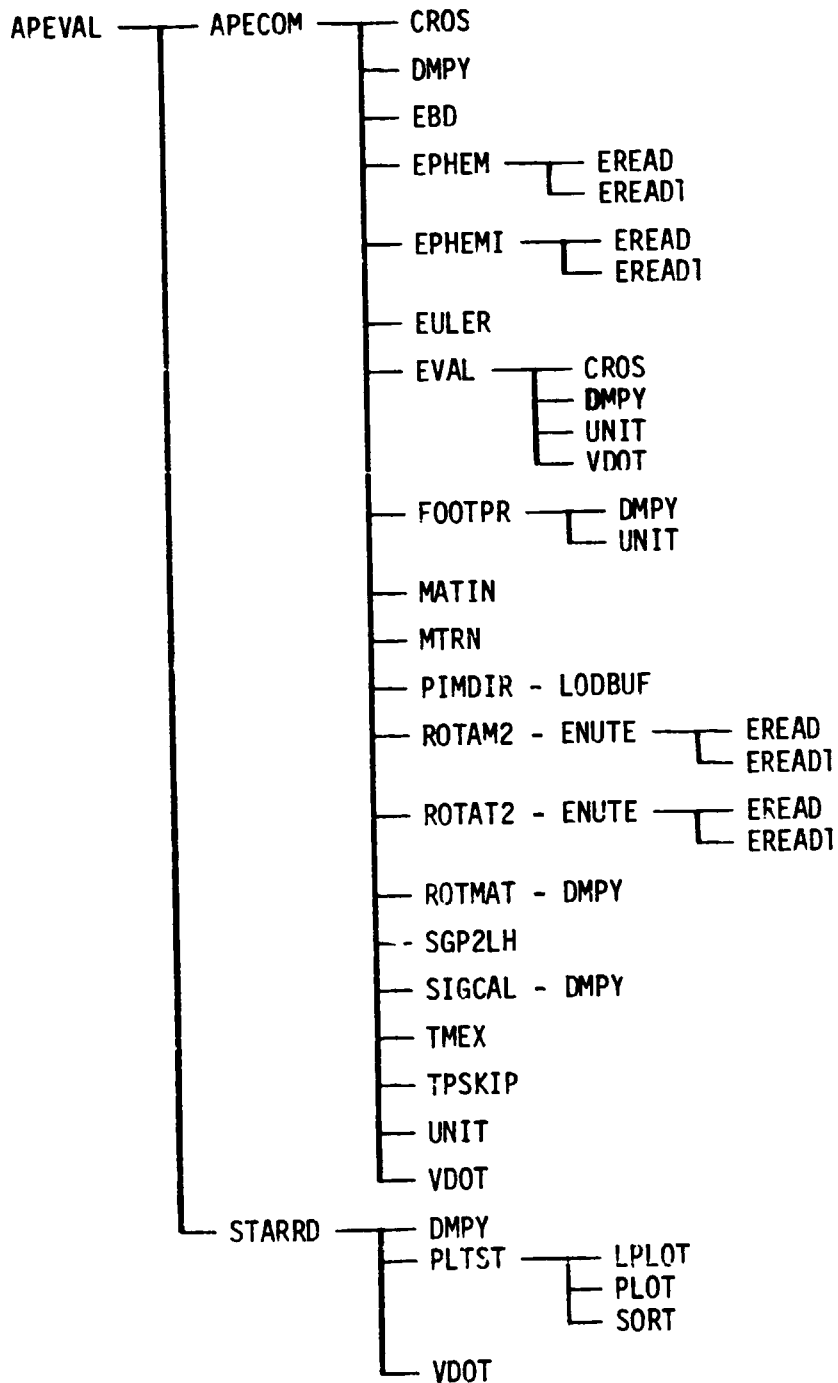
The third segment includes STARRD, PLTST, PLOT, LPL0T, and SORT. The core location assignments for this segment are 0023215 to 0030177 for code and from 0063472 to 0076771 for data,

The second and third segments overlay each other in APEVAL for the Apollo stellar camera case (for the case of ISLT 1, ISHFTR = 3).

3.2 SUBROUTINE DEPENDENCIES

This subsection contains a dependency chart of APE elements and a dependent element cross-reference table. In both cases the entry point name has been used instead of the element name where the entry point name differs from the element name.

3.2.1 Dependency Chart



3.2.2 Dependent Element Cross-Reference

<u>Name, Entry & Element</u>	<u>Referenced By These Elements</u>
APECOM	APEVAL
CROS	APECOM EVAL
DMPY	APECOM EVAL FOOTPR ROTMAT SIGCAL STARRD
EBD	APECOM
{ ENUTE (EPHEM)	GHA2 ROTAM2 ROTAT2
{ EPHEM (EPHEM)	APECOM
{ EPHEMI (EPHEM)	APECOM
{ EREAD (EREAD)	ENUTE EPHEM EPHEMI
{ EREADI (EREAD)	ENUTE EPHEM EPHEMI
EULER	APECOM
EVAL	APECOM
FOOTPR	APECOM
LODBUF	PIMDIR
LPLOT	PLTST
MATIN	APECOM
MTRN (MATOPS)	APECOM
PIMDIR	APECOM
PLOT	PLTST
PLTST	STARRD
{ ROTAT2 (ROTAT2)	APECOM
{ ROTAM2 (ROTAT2)	APECOM
ROTMAT	APECOM
SGP2LH	APECOM
SIGCAL	APECOM
SCRT	PLTST
STARRD	APEVAL
TMEX	APECOM
TPSKIP	APECOM
UNIT	APECOM EVAL FOOTPR
VDOT	APECOM EVAL STARRD

3.3 VARIABLE DEFINITIONS

Any variable in a subroutine can be classified in various ways. For example,

- | | |
|--|---------|
| a. Common variable | (CV) |
| b. Input/output variable into/from each subroutine | (IS/OS) |
| c. APE program input variable | (IV) |
| d. APE program output variable | (CV) |
| e. Unused variable (left over from previous version) | (TV) |
| f. Internal variable in each subroutine | (SV) |

In this document, the above example convention has been adopted and the abbreviated symbols in the parentheses will be used in this and later sections.

Item (a), the common variables, is listed under each common block name in Section 3.4.

Item (b), the input and output variables under each subroutine subtitle of the few selected principal subroutines, will be discussed in detail in Section 3.5.

Item (c), the APE program input variables supplied to APE by way of namelist, input data card, or input tape, is discussed in detail in Section 4.1. Among those IS variables, a number of dummy program input variables are identified and listed. Table 4-4 is a list of the TV variables.

Item (d), the APE program output variables which are written by APE on output units, tape, or on-line (but not on punched card form), will be discussed in detail in Section 4.2.

Item (e), the unused variables which are present in the various subroutines, will be discussed together with special cases of items a, b, c, or d. The TV variables must be identified if they also are IV or IS. This is necessary, because the TVs are not hidden left over variables but are visible input variables which need to be identified.

Item (f), the internal variables in each subroutine, will be discussed only if they are computed in the subroutines described in Section 3.5. In this document, SV includes OV but excludes IV.

3.4 COMMON VARIABLES

APE has 19 common blocks including a blank common but uses only the blank common and 11 labeled commons. The common blocks used are listed below.

<u>Common Label Name</u>	<u>Elements Referenced</u>
blank common	APECOM EVAL STARRD
AET	APECOM EVAL
BDGENI	APECOM EVAL EBD
CONST	APECOM EVAL
EVIN	APECOM EVAL
GDATA	APECOM EVAL
KOPAN	APECOM LODBUF
OMEGAI	APECOM EVAL
PAP	APECOM EVAL
SGTOCM	APECOM EVAL FOOTPR
SIGVAR	APECOM SIGCAL
STRECD	PLTST STARRD

The follow seven common blocks are not used and are given no further consideration here.

<u>Unused Common</u>	<u>Elements Referenced</u>
RCBIG	APECOM EBD
BCMAN	APECOM EBD
BDNP	EBD
BCNPTS	APECOM EBD
BCR	EBD
BCTGT	APECOM EBD
MASTER	APECOM

3.4.1 Blank Common Block

The blank common block is used in three subroutines, APECOM, EVAL and STARRD. It contains the following fifty-five CV, mixed mode variables.

COMMON//IPRS

COMMON//ALOW, AHIGH, DLOW, DHIGH, MTAPE, DELT, BRILL, INUM, TEMPG, RABER

1, CFL, T3, NINV, K1, K2, STEROT

2, JDYSHP, LCHJD, TSTART, TSTOP, IFIRST, DELTME

3, HPETME

<u>Common Variable (CV) Name</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description (section where defined)</u>
IPRS	0	1	I	IV/APECOM, IS/EVAL (§ 4.1.1).
ALOW	0	2-3	D.P.	SV/APECOM, AL/SV/STARRD.
AHIGH	0	4-5	D.P.	SV/APECOM, AH/SV/STARRD.
DLOW	0	6-7	D.P.	SV/APECOM, DL/SV/STARRD.
DHIGH	0	8-9	D.P.	SV/APECOM, DH/SV/STARRD.
MTAPE	0	10	I	IV/APECOM, IS/STARRD (§ 4.1.1).
DELT	0	11	Real	IV, CV not used.
BRILL	0	12	Real	SV/STARRD, CV and IV not used.
INUM	0	13	I	SV/STARRD, CV not used.
TEMPG	0	14-15	D.P.	SV/APECOM, IS/STARRD.
RABER(I)	3	16-21	D.P.	SV/APECOM, IS/STARRD.
CFL	0	22	Real	IV/APECOM, SV/EVAL, IS/STARRD.
T3(I,J) = NMTRX(I,J)	(3,3)	23-40	D.P.	SV/APECOM, IS/STARRD.
NINV(I,J)	(3,3)	41-58	D.P.	SV/APECOM, IS/STARRD (=STEROT(I,J)).
K1	0	59	Real	SV/APECOM, IS/STARRD, XK1/IS/PLTST.
K2	0	60	Real	SV/APECOM, IS/STARRD, XK2/IS/PLTST.
STEROT(I,J)	(3,3)	61-78	D.P.	SV/APECOM, IS/STARRD.

Blank Common Block (Continued)

<u>Common Variable (CV) Name</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description (section where defined)</u>
JDYSHP	0	79-80	D.P.	OS/TMEX, SV/APECOM, CV not used.
LCHJD	0	81-82	D.P.	OS/TMEX, SV/APECOM, CV not used.
TSTART	0	83-84	D.P.	SV/APECOM, CV not used.
TSTOP	0	85-86	D.P.	SV/APECOM, CV not used.
IFIRST	0	87	I	SV/APECOM, CV not used.
DELTME	0	88-89	D.P.	SV/APECOM, CV not used.
HPETME(1)	6	90-101	D.P.	IV/APECOM, CV not used (§ 4.1.2).

3.4.2 Common/AET/

The labeled common/AET/ is used in two subroutines, APECOM and EVAL. There is only one double precision variable in this common block.

COMMON/AET/GNTME

<u>Common Variable (CV) Name</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
GNTME	0	1-2	D.P.	G&N time in seconds, defined as GNTME = 60.*TGIMBL - BASTIM. SV/APECOM,IS/EVAL

3.4.3 Common/BCGENI/

The labeled common/BCGENI/ is used in three subroutines, APECOM, EBD, and EVAL. It contains 35 single precision, real variables. All except the first four variables are TV; i.e., unused variables.

COMMON/BCGENI/GM, RMOON1, ETUT, RA,
 CCC(4), CCC(9), CANO(2), CAM(7)
 X,D(2), APL(2), APW(2), CAMA(3)

Name of Common
 Variable (CV)
 Used in APE

	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
GM = UM	0	1	Real	IV/APECOM, moon's gravitational constant (km^3/sec^2)
RMOON1 = RM	0	2	Real	SV/APECOM, moon's local radius (km)
ETUT	0	3	Real	SV/APECOM, ETUT = DETUT*60.0 (min)
RA = REARTH	0	4	Real	SV/APECOM, RA = RE (km)
CC(I)	4	5-8	Real	TV
CCC(I)	9	9-17	Real	TV
CANO(I)	2	18-19	Real	TV
CAM(I)	7	20-26	Real	TV
D(I)	2	27-28	Real	TV
APL(I)	2	29-30	Real	TV
APW(I)	2	31-32	Real	TV
CAMA(I)	3	33-35	Real	TV

3.4.4 Common/CONST/

The labeled common/CO,ST/ is used in two subroutines, APECOM and EVAL. It contains five mixed mode variables. The first three variables are conversion factors assigned through data statements in APECOM.

COMMON/CONST/KM2FT,ET2FT,DTOR,F,MN

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
KM2FT	0	1-2	D.P.	SV/APECOM, KM2FT = 5702383.60832D + 0
ER2FT	0	3	Real	SV/APECOM, ER2FT = 20925738.19E + 0
DTOR	0	4-5	D.P.	SV/APECOM, DTOR = 0.017453292519943D + 0
F	0	6	Real	SV/APECOM, F = CFL (IV/APECOM)
MN	0	7	I	SV/APECOM, MN = MISSNO (IV/APECOM)

3.4.5 Common/EVIN/

The labeled common/EVIN/ is used in two subroutines, APECOM and EVAL. It contains eight double precision variables which are all calculated in APECOM and are transferred into EVAL as S/EVAL . The units of PM(I) and ZJ(I) are converted from feet to km in EVAL.

COMMON/EV IN/DPHANG, SUNELV, RMBAR, ZJ

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
LPHANG = RHO	0	1-2	D.P.	SV/APECOM, phase angle in radians
SUNELV	0	3-4	D.P.	SV/APECOM, sun elevation angle in radians
RMBAR(1) = PM(I)	3	5-10	D.P.	SV/APECOM, unit vector of surface vertical at principal ground point
ZJ(I)	3	11-16	D.P.	SV/APECOM, unit vector of camera optical axis

3.4.6 Common/GDATA/

The labeled common/GDATA/ is used in two subroutines, APECOM and LODBUF. It contains 9,074 mixed mode variables. Ten of these variables, ELEMDO(1) and (2), ELEMDO(1) and (2), ELEMDO(1) and (2); and ITRUN(1)...(4) are TV and 3007, SHAFT(1)...(500), TRUN(1)...(1,000), STIME(1)...(501), TTIME(1)...(1,000), ISHFTR, ISHFT(1)...(4) and ITELE are not CV in the true sense since they are not used in the subroutine LODBUF.

COMMON/GDATA/TGO, TGI, TGM, TGOTME, TGITME, TGMTME, SHAFT, TRUN, STIME

- 1, TTIME, IOUTER, IINNER, IMID, ELEMDO, ELEMDO, ELEMDO
- 2, ITNOW, GBTMIN, ISHFTR
- 3, ISHFT(4), ITRUN(4)
- 4, TDATA, BTRTL, BTRTH
- 5, ITELE
- 6, INDX

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
TGO(I)	1000	1-2000	D.P.	SV/APECOM, IS, SV/LODBUF
TGI(I)	1000	2001-4000	D.P.	SV/APECOM, IS, SV/LODBUF
TGM(I)	1000	4001-6000	D.P.	SV/APECOM, IS, SV/LODBUF
TGOTME(I)	1000	6001-8000	D.P.	SV/APECOM, IS, SV/LODBUF
TGITME(I)	1000	8001-10000	D.P.	SV/APECOM, IS, SV/LODBUF
TGMTME(I)	1000	10001-12000	D.P.	SV/APECOM, IS, SV/LODBUF
SHAFT(I)	500	12001-13000	D.P.	SV/APECOM, IS/PIMDIR, TV/LODBUF (CV not used)
TRUN(I)	1000	13001-15000	D.P.	SV/APECOM, IS/PIMDIR, TV/LODBUF (CV not used)
STIME(I)	501	15001-16002	D.P.	SV/APECOM, IS/PIMDIR, TV/LODBUF (CV not used)
TTIME(I)	1000	16003-18002	D.P.	SV/APECOM, IS/PIMDIR, TV/LODBUF (CV not used)
IOUTER(I)	4	18003-18006	I	IV'APECOM, IS/LODBUF

3.4.6 Common/GDATA/ (Continued)

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
IINNER(I)	4	18007-18010	I	IV/APECOM, IS/LODBUF
IMID(I)	4	18011-18014	I	IV/APECOM, IS/LODBUF
ELEMDO(I)	2	18015-18016	Real	TV
ELEMDI(I)	2	18017-18018	Real	TV
ELEMDM(I)	2	18019-18020	Real	TV
ITNOW	0	18021	I	IV/APECOM, IS/LODBUF
GBTMIN	0	18022-18023	D.P.	SV/APECOM, IS/LODBUF
ISHFTR	0	18024	I	IV/APECOM, TV/LODBUF (CV not used)
ISHFT(I)	4	18025-18028	I	IV/APECOM, TV/LODBUF (CV not used)
ITRUN(I)	4	18029-18032	I	TV
TDATA(K,J)	(4,10)	18033-18072	Real	IV/APECOM, IS/LODBUF
BTRL	0	18073	Real	IV/APECOM, (also set BTRL = .10), IS/LODBUF
BTRTH	0	18074	Real	IV/APECOM (also set BTRTH = .02), IS/LODBUF
ITELE	0	18075	I	IV/APECOM, TV/LODBUF (CV not used)
INDX	0	18076	I	SV/APECOM, IS/LODBUF

3.4.7 Common/KOPAN/

The labeled common/KOPAN/ is used in two subroutines, APECOM and EVAL. It has the single integer mode variable KOPAN. For all APE applications other than those for which ISHFTR = 4 (panoramic camera), KOPAN is TV and needs no further consideration. For these applications where ISHFTR = 4 (panoramic camera), KOPAN is read in from the fifth card group at sequence number 389 of APECOM. Note that the second character of the variable title is zero and not the letter O.

COMMON/KOPAN/KOPAN

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
KOPAN	0	1	I	IV, IS/APECOM, IS, OS/EVAL

3.4.8 Common/OMEGAI/

The labelled common/OMEGAI/ is used in two subroutines, APECOM and EVAL. It has one double precision variable, OMEGAI which is the IR scanner instantaneous rotational rate in radians/second and is supplied to APECOM from the non-standard special trajectory FORMAT3 data tape as DUM82(44).

COMMON/OMEGAI/OMEGAI/

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
OMEGAI	0	1-2	D.P.	SV/APECOM, IS/EVAL

3.4.9 Common/PAP/

The labeled common/PAP/ is used in two subroutines, APECOM and EVAL. It contains the following 186 mixed mode variables:

COMMON/PAP/DUM9, DCSVSG, DUM18, DUM28, DUM30, ALTIM, PFOOT, IRAHRS,
 * IRAMIN, RASEC, IRADC, IDECDG, IDECMN, DECSEC, IDAY, IHR, IMIN,
 * FSEC, IFRAME, TILT, AZM, LONG, LAT, CMLAT, CMLNG, ELVS, PHANG,
 * SAZ, PHI, OMEGA, KAPPA, TITLE, COPT, GMTYR, GMTMTH, GMTDAY,
 * GMTHR, GMTMIN, GMTSEC, IRFLAG

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
DUM9(I)	9	1-18	D.P.	A11 TV, except DUM9(1), (2), and (5); SV/APECOM, IS/EVAL IS/EVAL
DCSVSG(I)	3	19-24	D.P.	SV/APECOM, IS/EVAL
DUM18(I)	18	25-42	Real	A11 TV, except DUM18(10...(18), SV/APECOM, OV/EVAL
DUM28(I)	28	43-98	D.P.	SV/APECOM, TV/EVAL (CV not used)
DUM28(1)	-	-	-	TV
DUM28(2)...(3)	-	-	-	DVEL(1)...(3)/IV/APECOM, TV/EVAL (CV not used)
DUM28(4)...(6)	-	-	-	TV
DUM28(7)...(10)	-	-	-	SV/APECOM, IS, OV/EVAL
DUM28(11)...(16)	-	-	-	TV
DUM28(17)...(19)	-	-	-	SV/APECOM, IS/EVAL
DUM28(20)...(25)	-	-	-	TV
DUM28(26)...(28)	-	-	-	TV
DUM30(I)	30	99-158	D.P.	

3.4.9 Common/PAP/ (Continued)

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
DUM30(1)...(3)	-	-	-	SV/APECOM, TV/EVAL (CV not used)
DUM30(4)...(6)	-	-	-	SV/APECOM, IS, OV/EVAL, X-, Y-tilts and heading
DUM30(7)...(9)	-	-	-	SV/APECOM, TV/EVAL (CV not used)
DUM30(10)...(18)	-	-	-	SV/APECOM, IS, OV/EVAL, LH2CM(1.1) ... (LH2CM(3.3))
DUM30(19)...(27)	-	-	-	SV/APECOM, IS, OV/EVAL, SC2CM(1.1) ... SC2CM(3.3)
DUM30(28)...(30)	-	-	-	SV/APECOM, TV/EVAL (CV not used)
ALTIM(1)	3	159-161	Real	SV/APECOM, IS, OV/EVAL, laser vehicle altitude in km
ALTIM(2)	-	-	-	SV/APECOM, IS, OVEVAL, laser slant range in km
ALTIM(3)	-	-	-	TV
PFOOT(1)	(8,7)	162-217	Real	SV/APECOM, IS, OVEVAL, latitude and longitude of footprints
IRAHRS	0	218	I	SV/APECOM, IRA(1)/OV/EVAL, right ascension (hr)
IRAMIN	0	219	I	SV/APECOM, IRA(2)/OV/EVAL, right ascension (min)
RASEC	0	220	Real	SV/APECOM, OV/EVAL, right ascension (sec)
IRADC	0	221	I	SV/APECOM, IS/EVAL, print flag
IDECDG	0	222	I	SV/APECOM, OV/EVAL, declination (deg)

3.4.9 Common/PAP/ (Continued)

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
IDECMN	0	223	I	SV/APECOM, OV/EVAL, declination (min)
DECSEC	0	224	R	SV/APECOM, OV/EVAL, declination (sec)
IDAY	0	225	I	SV, IV, OV/APECOM, OV/EVAL
IHR	0	226	I	IV, SV, OV/APECOM, OV/EVAL
IMIN	0	227	I	IV, SV, OV/APECOM, OV/EVAL
FSEC	0	228	Real	SV, IV, OV/APECOM, OV/EVAL
IFRAME(1)	2	229-230	I	
IFRAME(1)	-	-	-	IV, SV, OV/APECOM, K/OV/EVAL
IFRAME(2)	-	-	-	IV, SV, OV/APECOM, TV/EVAL (CV not used)
TILT	0	231	Real	SV, OV/APECOM, OV/EVAL, tilt angle (deg)
AZM	0	232	Real	SV, OV/APECOM, SV, OV/EVAL, tilt azimuth (deg)
LONG	0	233	Real	SV, OV/APECOM, XLO/SV, OV/EVAL, longitude of nadir point
LAT	0	234	Real	SV, OV/APECOM, XLA/SV, OV/EVAL, latitude of nadir point
CMLAT	0	235	Real	SV, OV/APECOM, XLAC/OV/EVAL, latitude camera axis
CMLNG	0	236	Real	SV, OV/APECOM, XLOC/OV/EVAL, longitude camera axis intersection
ELVS	0	237	Real	SV, OV/APECOM, SV/EVAL

3.4.9 Common/PAP/ (Continued)

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
PHANG	0	230	Real	SV, OV/APECOM, PHASE/OV/EVAL (deg)
SAZ	0	239	Real	SV, OV/APECOM, SAI/OV/EVAL, sun azimuth
PHI	0	240	Real	SV, /APECOM, OV/EVAL (deg)
OMEGA	0	241	Real	SV, /APECOM, OV/EVAL (deg)
KAPPA	0	242	Real	SV, /APECOM, OV/EVAL (deg)
TITLE(I)	4	243-246	Real	IV, OV/APECOM, OV/EVAL
COPT(I)	3	247-252	D.P.	SV/APECOM, SV/EVAL, spacecraft direction cosines
GMTYR	0	253	I	SV, OV/APECOM, IGMT(1)/OV/EVAL
GMTMTH	0	254	I	SV, OV/APECOM, IGMT(2)/OV/EVAL
GMTDAY	0	255	I	SV, OV/APECOM, IGMT(3)/OV/EVAL
GMTHR	0	256	I	SV, OV/APECOM, IGMT(4)/OV/EVAL
GMTMIN	0	257	I	SV, OV/APECOM, IGMT(5)/OV/EVAL
GMTSEC	0	258-259	D.P.	SV, OV/APECOM, OV/EVAL
IRFLAG	0	260	I	SV, /APECOM, SV/EVAL

3.4.10 Common/SGTOCM/

The labeled common/SGTOCM/ is used in three subroutines, APECOM, EVAL, and FOOTPR. It contains nine double precision variables which are the elements of the transformation matrix, SG2CM(3,3).

COMMON/SGTOCM/SG2CM

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
SG2CM(I,J)	(3,3)	1-18	D.P.	SV/APECOM, IS/EVAL, IS/FOOTPR

3.4.11 Common/SIGVAR/

The labeled common/SIGVAR/ is used in two subroutines, APECOM and SIGCAL. It contains 99 double precision variables and is used only for special IR scanner applications.

COMMON/SIGVAR/PUIVK, PUIVKT, LAMDAC

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
PUIVK(I,J)	(1,9)	1-18	D.P.	SV/APECOM, IS, SV/SIGCAL
PUIVKT(I,J)	(9,1)	19-36	D.P.	TV/APECOM, SV/SIGCAL (CV not used)
LAMDAC(I,J)	(9,9)	37-198	D.P.	SV/APECOM, IS, SV/SIGCAL

3.4.12 Common/STRECD/

The labeled common/STRECD/ is used in two subroutines, PLTST and STARRD. It contains Z(5,200) or C(5,200) single precision variables for use in the star patterns. They are selected from the star catalog by STARRD and are used in PLTST.

COMMON/STRECD/Z or COMMON/STRECD/C

<u>Name of CV</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Description</u>
Z(I,J) = C(I,J)	(5,200)	1-1000	Real	SV/STARRD, IS, SV/PLTST
C(1,J)	-	-	-	Y- diapositive coordinate of Jth star
C(2,J)	-	-	-	X- diapositive coordinate of Jth star
C(3,J)	-	-	-	Magnitude of Jth star
C(4,J)	-	-	-	BOSS number of Jth star
C(5,J)	-	-	-	SAO number of Jth star

3.4.13 Unused Common Blocks

The following seven common blocks containing 3,090 variables in mixed modes are not used and should be ignored.

<u>Name of TV Common Block</u>	<u>Name of Variables</u>	<u>Dimension</u>	<u>Position</u>	<u>Type</u>	<u>Elements Referenced</u>
BCBIG	BIG(I)	100	1-100	Real	TV/APECOM, TV/EBD
BCMAN	MAN(I)	30	1-30	Real	TV/APECOM, TV/EBD
BCNP	XNPH(I)	480	1-480	Real	TV/EBD
	XNPL(I)	420	481-900	Real	TV/EBD
BCNPTS	NPTS(I)	370	1-370	Real	TV/APECOM, TV/EBD
BCR	R(I)	100	1-100	Real	TV/EBD
	RID(I)	20	101-120	Real	TV/EBD
	RZ(I)	100	121-220	Real	TV/EBD
BCTGT	TGT(I)	10	1-1	Real	TV/APECOM, TV/EBD
MASTER	IPOINT(I)	120	1-120	I	TV/APECOM
	CONST(I)	450	121-1020	D.P.	TV/APECOM
	KONST(I)	120	1021-1140	I	TV/APECOM
	CONFIX(I)	320	1141-1460	Real	TV/APECOM
	KONFIX(I)	450	1461-1910	I	TV/APECOM

3.5 SUBROUTINE DESCRIPTION

This section briefly describes each of the 27 elements used by APE. APE has one main program, APEVAL, the element with an asterisk (*): one MAP, T1, the elements with blocks; 25 subroutines which have 39 entry points all together; and one function routine, PIMDIR, which is underlined. Those with parentheses, such as (EPHEMI) or (ENUTE), are the additional routine entries which differ from the element name.

<u>Name of Element</u>	<u>Description</u>
APECOM	Computes vehicle-instrument-moon geometry and target lighting
APEVAL*	Main driving program of APE
DMPY	Multiplies double precision matrices of the form $A \cdot B$
EBD	Initializes the constant array
EPHEM (EPHEMI) (ENUTE)	Reads and interpolates JPL planetary ephemeris
EREAD (EREADI)	Reads the data record containing the date from JPL ephemeris tape
EULER	Computes Euler angles from the LH2CM rotation matrix
EVAL	Output processor of APE
FOCTPR	Computes the footprints which are the projections of points on the photo format onto the mean lunar surface
LODBUF	Reads and buffers the input telemetered data
LPLOT	Loads plot array for star pattern
MATIN	Matrix inversion routine
MATOPS	A multi-entry point, matrix operations routine
(MSUBT)	Subtraction : $C = A - B$
(MADDA)	Addition : $C = A + B$
(MMOV)	Move and copy : $C = A$
(MTRN)	Transpose : $C = A^T$
(MMPY)	Multiplication: $C = A \cdot B$

<u>Name of Element</u>	<u>Description</u>
PIMDIR	A four point interpolation function routine
PLOT	Plots an online star pattern
PLTST	Tabulates data for plotted stars
ROTAT2	Rotates a vector from one time based co-ordinate system to another
(ROTAM2)	Computes rotation matrices necessary to rotate from one coordinate system to another coordinate system
(GHA2)	Computes Greenwich hour angle
RCTMAT	Rotates the camera axes coordinate system about its Z-axis to position its X-axis to lie within 45° of the velocity vector direction
SGP2LH	Computes SG2LH rotation matrix from selenographic input vector
SIGCAL	Computes σ_ϕ , σ_Ω , σ_{TX} , σ_{KAP} , σ_{TILT} , σ_{ASM} , σ_{TY} , σ_{HDG} , or σ_{SNG}
SORT	Sorts the star array in preparation for the star pattern plot
STARRD	Reads star catalog tape and selects the brighter stars within the stellar camera FOV
SUBPAC	Calculates partial derivative terms for the sigma definitions
[T1]	MAP for the partitioning and overlaying of APE
TPSKIP	Skips pseudo end-of-files (EOR) of HCPE trajectory special format 3 tape
TMEX	Converts year, month, day of Julian date
VECT	A multi-entry point, double precision vector operation routine
(UNIT)	$\bar{V}_3 = \text{Unit}(\bar{V}_1)$
(VDOT)	$e = \bar{V}_1 \cdot \bar{V}_2$
(CROS)	$\bar{V}_3 = \bar{V}_1 \times \bar{V}_2$
(SDOT)	$V_3 = a\bar{V}_1$

The following are brief structured descriptions of the four major computational elements of APE. These are the subroutines APECOM, EVAL, STARRD, and FOOTPR.

3.5.1 APECOM

- PURPOSE - Computes photo analysis support data from vehicle trajectory and attitude information
- COMMON - /blank/, /AET/, /CGENI/, /CONST/, /EVIN/, /GDATA/, /KOPAN/, /OMEGAI/, /PAP/, /SGTOCM/, and /SIGVAR/
(unused common: MASTER, BCBIG, BCMAN, BCMPTS, BCTGT)
- USAGE - Call APECOM (ISLT, ASTAR, ZROT, CTM, STM)
 - (IS) - Calling sequence: none
 - Common : none
 - (OS) - Calling sequence: ISLT $\left\{ \begin{array}{l} = 0 \text{ with no stellar camera} \\ \geq 2 \text{ with stellar camera} \end{array} \right\}$

ASTAR(1,1)...(3,3) = BD2CM(1,1)...(3,3)
= TV output

ZROT(1,1)...(3,3) = $\begin{vmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & +1 \end{vmatrix}$
= TV output

CTM = TV namelist input (INPUT1)
= TV output

STM = TV namelist input (INPUT1)
= TV output

- Common (blank) : IP&S = TV

ALOW

AHIGH

DLOW

DHIGH

MTAPE = Star catalog tape unit number
= IV through namelist (INPUT1)

DELT = TV = TV output

BRILL = not CV = TV output

INUM = not CV = TV output

TEMPG

RABER

CFL

NMTRX

NINV

K1

K2

STEROT

- UNITINES REQUIRED - PIMDIR, EBD, EPHEM, FSBSFL, TPSKIP, NTRAN, TMEX, EVAL, MTRN, DMPY, ROTAM2, SGP2LH, EULER, ROTMAT, UNIT, FOOTPR, MATIN, EPHEMI, EXIT, ROTAT2, VDOT, CROS, SIGCAL
- TAPES REQUIRED
 - Units and descriptions: A(JPL19), B(FORMAT3 TRAJ), C(GIMBAL), and D(APE output)
 - Tape rewind at: 209C 216D 223B 976A 1418D
 - Tape end of file at: 1419D
 - Tape read at: 262C 324B 347B
 - Tape write at: 329D
- ONLINE OUTPUT
 - At: 221 265 340 342 350
377 406 433 877 879
979 1018 1059 1062 1064
1066 1069 1071 1318 1321
1330

3.5.2 EVAL

- PURPOSE
 - The APE output processor which converts units, formats, and writes the photo evaluation support data for online printout and output to the tape assigned to unit D.
- COMMON
 - /blank/, /AET/, /BCGENI/, /CONST/, /EVIN/, /KOPAN/, /OMEGAI/, /PAP/, and /SBTODM/ (all common blocks are used effectively in subroutine EVAL).
- USAGE
 - (IS)
 - Call EVAL
 - Calling sequence: none
 - Common: all above nine common blocks
 - (OS)
 - Calling sequence: none
 - Common: none
 - (SV,OV)
 - A = Semi-major axis of vehicle path (km)
 - ALPHA = Reflectance longitude

ALT = Vehicle altitude
 C = Magnitude of $-ZJ$
 DAN = North deviation angle
 E = Eccentricity of vehicle orbit
 EPS = Emission angle
 F = Camera focal length in same units as C
 HDOT = Mean altitude rate (km/sec)
 LATLIR = Latitude of approximate IR scanner limb crossing (leading)
 LATTIR = Latitude of approximate IR scanner limb crossing (trailing)
 LONLIR = Longitude of approximate IR scanner limb crossing (leading)
 LONTIR = Longitude of approximate IR scanner limb crossing (trailing)
 NU = True anomaly
 P = Semi-latus rectum of the vehicle orbit
 R = Vehicle radius
 RDOTSG = Vehicle velocity vector (selenographic)
 RHO = Phase angle
 RM = Local lunar radius
 RSG = Vehicle position vector (selenographic)
 SF = Scale factor
 SG2CM = Transformation matrix SGTOCM
 SSLN = Longitude of subsolar point
 SSLT = Latitude of subsolar point
 SUNELV = Sun elevation angle
 SUNIT = Sun unit vector (selenographic)
 SWING = Swing angle
 TH = Angle from instrument aiming axis at scan center time to the mean lunar horizon
 TL = Tilt to leading horizon
 TT = Tilt to trailing horizon
 UM = Moon gravitational constant
 VAZ = Azimuth of velocity vector
 VTHETA = Horizontal velocity (km/sec)

TEMPG

RADER

CFL = Camera focal length
(meters)

NMTRX

NINV

K1

K2

STEROT

(OS)

- Calling sequence: None
- Common (STRECD) : C(1,1)...C(5,200) = 0V but not OS or CV

- ROUTINE REQUIRED - DMPY, VDOT, PLTST

- TAPE REQUIRED
 - Units and descriptions: MTAPE (star catalog input tape); usually MTAPE = 4 for X-tape
 - Tape rewind at: 33X, 65X, 131X
 - Tape backspace at: 37X
 - Tape read at: 41X
 - Tape write: None

- ONLINE OUTPUT
 - At: 71, 76, 112, 115

3.5.4 FOOTPR

- PURPOSE
 - Calculates latitudes and longitudes of photo footprint boundary points.
- COMMON
 - /SGTOCM/
- USAGE
 - Call FOOTPR (PSG, DUM82, DWI, DLI, DI, CFL, CFOOT, RMOON)

(IS)

- Calling sequence: PSG(1), (2), and (3)
DUM82(1)...(82) = TV

DWI

DLI

DI

CFL = Camera focal length

RMOON

(OS) - Common (SGTOCM): SG2CM(1,1)...(3,3)
 - Calling sequence: CFOOT(1)...(8)
 - Common: None

- ROUTINES REQUIRED - DMPY, UNIT
- TAPE REQUIRED - None
- ONLINE OUTPUT - None

4. USER'S GUIDE

4. USER'S GUIDE

This section presents information, instructions, and requirements for execution of the APE program on a UNIVAC 1108 computer. It includes descriptions of the required system configurations and of all card and tape inputs for the various APE application types. It also includes instructions for the preparation and assembly of all required APE inputs.

The UNIVAC 1108 system configurations required for the execution of APE are shown in Table 4-8. For the general application of APE, the required configuration is achieved through the following UNIVAC 1108 unit assignments.

- Unit A - JPL ephemeris (Fastrand file)
- Unit B - HOPE trajectory tape (format 3)
- Unit C - Vehicle attitude data tape
- Unit D - Output data tape
- Unit Z - APE PCF tape

The APE input deck setup for the general application is shown in Figure 4-1. The additional I/O requirements for special applications of APE are summarized in Table 4-1.

The APE program is available on two TRW 800 bpi, 7-track magnetic tapes: TRW00157 and TRW00163. These tapes are available in the TRW ancient tape library. The first file of these tapes contains all relocatable elements while the symbolic elements are contained on the second file.

Tape TRW00157, the primary APE program tape, can be operated without any alters for the generation of support data for CSM mounted cameras. Support data for the panoramic camera and the lunar sounder is obtained by use of the proper alter decks described in Appendix A.

Tape TRW00163 is used only for IR scanner applications.

4.1 INPUT

The input deck setup required for execution of the generalized APE is shown in Figure 4-1. The detailed requirements for card and tape inputs are described in Sections 4.1.1 and 4.1.2, respectively.

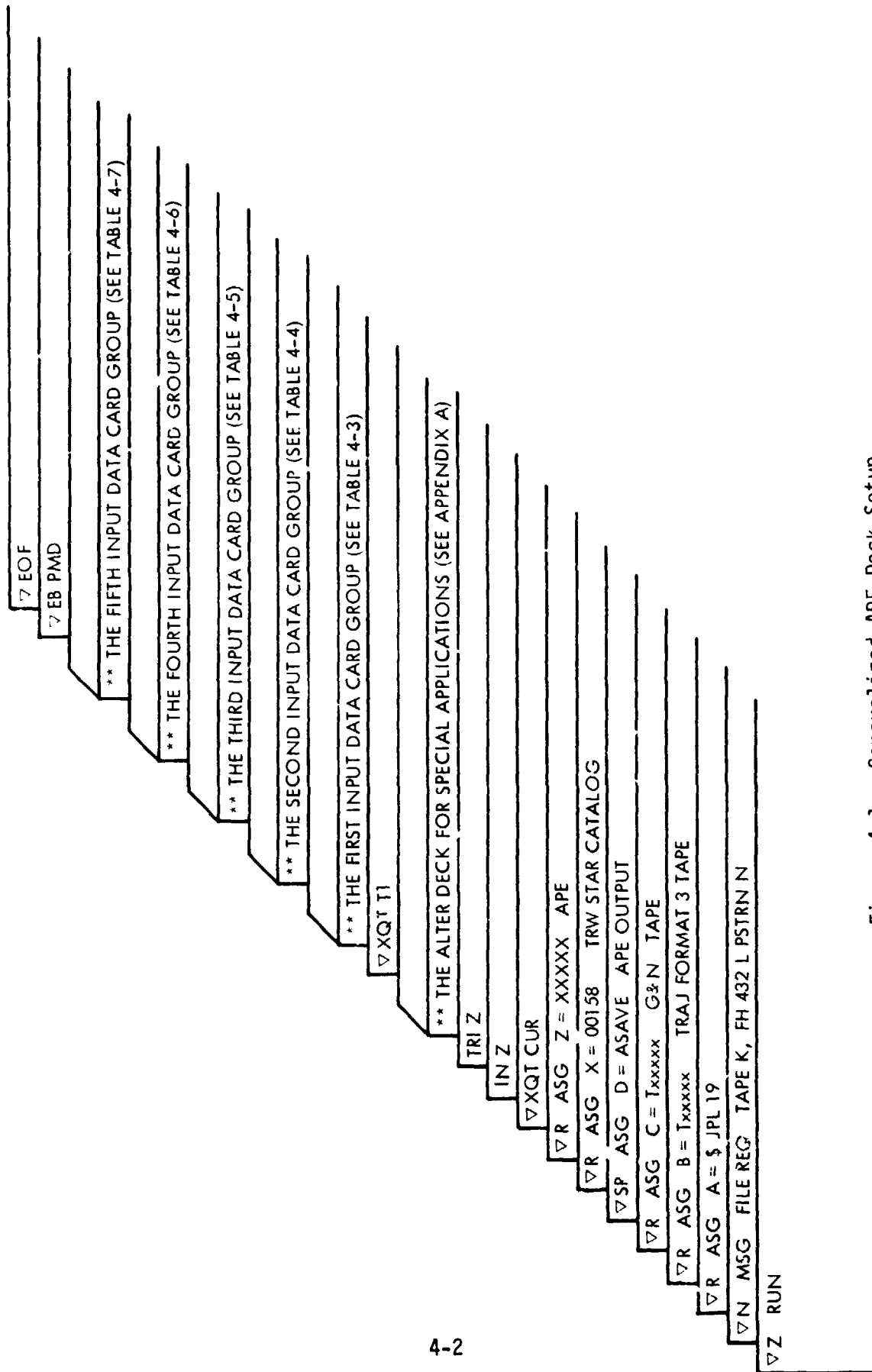


Figure 4-1. Generalized APE Deck Setup

Table 4-1. Additional I/O Requirements for APE Applications

Application (Camera or Instrument)	APE Mode (ISHFTR)	Program Alters	Additional Inputs Required	Application Outputs
Window mounted cameras	6	None	None	Standard on-line output; no output D-tape
Sextant camera	1	None	Gimbal data tape input must be in Apollo standard downlink format	Standard on-line output; no output D-tape
SIM-bay mapping camera	2	None	Third data card group (Table 4-5)	SIM-bay camera output on- line; also D-tape (Table 4-15)
Apollo pano- ramic camera	4	Alter deck for the pano- ramic camera (Appendix A.2)	Fifth data card group (Table 4-7)	Panoramic camera output on-line; also D-tape (Table 4-15)
Stellar camera	3	None	1. Third data card group 2. Star catalog tape (TRW) 3. Set ISSEQI and ISSEQF in Namelist/Input 1/	Special on-line star pat- tern plot and printout
Lunar sounder	2	Alter deck for the lunar sounder (Appendix A.1)	None	Two special output tapes on units E and F (Tables 4-17, 4-18); simplified on-line printout
Infrared scanner	5	None	Special trajectory tape, HOPE format 3 modified to include ω and scan center times	Special tape output on unit D (Table 4-16)

4.1.1 Card Inputs

The on-line input data card decks required for the execution of APE vary in content and order according to the program application. This is true for general as well as special applications since the input mode for two kinds of input data is optional regardless of the application type. Trajectory and vehicle attitude data may be input either by card or tape. Table 4-2 presents, in proper sequence for a generalized APE application, the basic elements of the APE input data deck. The various individual inputs of each of these elements are defined in Tables 4-3 through 4-7.

4.1.2 Tape

All the input tapes for APE are written in UNIVAC 1108 FORTRAN V binary format on 7-track, high density (800 bpi) magnetic tapes. The tape configuration for APE is shown in Table 4-8. The first three tapes, A, B, and C, are the input data tapes for a general application of APE. Tape X, the Apollo photo evaluation star catalog (TRW00158), is the input star catalog for the special stellar camera APE application. The D-tape can be the output tape for either general or special applications of APE. The last tape, Z, is the APE PCF tape (TRWXXXXX).

4.1.2.1 JPL19 Ephemeris on Fastrand File

The JPL ephemeris contains two information records at the beginning of each tape followed by the data records. The format for the data records is listed in Table 3-1, Section 3.2 of Reference 3. The step size of the logical data record is 8.0 days. All data, with the exception of those for nutations, are double precision so that the total record size is 1862 words.

The Julian date is the epoch (Ephemeris Time, ET) of the start of the data record. Lunar positions and velocities are referred to the geocentric equatorial rectangular reference frame of the mean equator and equinox of 1950.0 = JD 243,3282,423.

If data are required for a particular epoch in universal time (UT), the time correction $DETUT = ET - UT$ must be specified through the namelist input (INPUT1), in minutes.

Table 4-2. Generalized Input Data Card Setup

Sequence of Input Data Card Group	Description of Input Data Card Group	Defined In	Remarks
First	Title card	Table 4-3	For all cases
Second	namelist/INPUT1/ input cards	Table 4-4	For all cases
Third	SIM-bay mapping/ stellar camera data cards	Table 4-5	For application to photographic data with ISHFTR=2 or 3
Fourth	namelist/INPUT2/ input cards	Table 4-6	For all cases of IFLAG=0 or IFLAG=2 only
Fifth	Panoramic camera data cards	Table 4-7	For ISHFTR=4 only

Table 4-3. First Data Card Group (Title Card)

Read in at Sequence #212 of subroutine APECOM with Format #1890 as (4A6,I6).

<u>Input Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
PREFIX(1)	1-6	A6	TITLE(1), the first word of the title, as CV/PAP/.
PREFIX(2)	7-12	A6	TITLE(2), the second word of the title, as CV/PAP/.
Z2 (1)	13-18	A6	TITLE(3), the third word of the title, as CV/PAP/.
Z2 (2)	19-24	A6	TITLE(4), the fourth word of the title, as CV/PAP/.
IFRAME(1)	25-30	I6	IFRAME(1), as CV/PAP/.

Table 4-4. Second Data Card Group (Namelist Input/INPUT1/)

Total 325 variables in INPUT1; 206 IV and 119TV.

Input Variable	Description	Type/Input Value(Unit)
AU	The Moon-Sun vector in astronomical units	d.p./149,597,900(km)
BTRTH	High bit rate, only for Apollo 10, 12, and 14	Real/.02(1/sec)
BRTL	Low bit rate, only for Apollo 10, 12, and 14	Real/.10(1/sec)
CAMA(1)	FL = format length for Apollo photo frame	Real/ (mm)
CAMA(2)	FW = format width for Apollo photo frame	Real/ (mm)
CFL	Focal length	Real/ (m)
C1	Stellar camera half angle of view along Xs (forward)	d.p./ (deg)
C2	Stellar camera half angle of view along Ys (side).	d.p./ (deg)
DELTCL	Onboard clock zero (GMT) minus range zero (GMT)	Real/ (sec)
DETUT	Difference between ET (Ephemeris Time) and UT (Universal Time); (ET-UT) in minutes	d.p./ (min)
DUM32(1)...(82)	The first 82 double precision words of the data record of HOPE trajectory FORMAT3 tape	d.p./sec § 4.1.2
FL	Format length for Apollo photographic frame	Real/ (m)
FW	Format width for Apollo photographic frame	Real/ (m)
GM	Moon's gravitational constant	Real/4902.58(km ³ /sec ²)
IFLAG	Input flag designating source of telemetered gimbal and vehicle state data	I/ (N.D.)

Table 4-4. Second Data Card Group (Continued)
(Namelist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
IFLAG (continued)	= 0 for gimbal data through cards, trajectory data through cards = 1 for gimbal data through tape, trajectory data through cards = 2 for gimbal data through cards, trajectory data through tape = 3 for gimbal data through tape, trajectory data through tape	
IGMFLE	Number of files to be skipped or, the gimbal data tape	I/ (N.D.)
IINNER(1) & (2)	Word locations of inner gimbal angle in downlink buffer record	I/ (N.D.)
IINNER(3) & (4)	Element locations for timing difference computation for inner gimbal angle	I/ (N.D.)
IMID(1) & (2)	Word locations of middle gimbal angles in downlink buffer record	I/ (N.D.)
IMID(3) & (4)	Element locations for timing difference computations for middle gimbal angles	I/ (N.D.)
INT	Input flag to bypass interpolation of telemetered data. This is used only when actual telemetered values for specified times are to be used = 0 for interpolated telemetered data ≠ 0 for bypassing the interpolation of telemetered data	I/ (N.D.)

Table 4-4. Second Data Card Group (Continued)
(Hamelist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
IOUTER(1) & (2)	Word locations of outer gimbal angles in downlink tape buffer record	I/ (N.D.)
IOUTER(3) & (4)	Element locations for timing difference computations for outer gimbal angles	I/ (N.D.)
IPROBE	Input flag for diagnostic printout = 0 for nominal printout = 1 for nominal with additional printout for detection of improper telemetered or state vector input	I/O (N.D.)
IPRS	Number of pairs of footprint points required	I/1 (N.D.)
ISHFT(1) & (2)	Word locations of sextant shaft angles in downlink tape buffer record	I/ (N.D.)
ISHFTR	Input flag of instrument sensor (including camera) designation = 1 for sextant camera = 2 for SIM-bay mapping camera or star sounder = 3 for stellar camera = 4 for panoramic camera = 5 for infrared scanner = 6 for window mounted cameras	I/ (N.D.)
ISLT	Input flag for stellar camera ISLT = 2 for stellar camera ISLT = 0 for nonstellar camera	I/ (N.D.)

Table 4-4. Second Data Card Group (Continued)
(ilamelist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
ISSEQF	Input dummy frame number of star pattern (it should be a nonzero dummy frame number beyond the stop time)	I/ (N.D.)
ISSEQI	Input real frame number of star pattern to be predicted	I/ (N.D.)
ISTPRT	Print flag option for intermediate APE printout = 0 do print the intermediate printout ≠ 0 do not print the intermediate printout	I/ (N.D.)
ISVFLE	Number of files to be skipped on state vector input data tape	I/ (N.D.)
ITELE	Element location of TNOW for timing difference computations	I/ (N.D.)
ITNOW	Word location of TNOW in downlink tape buffer record	I/ (N.D.)
ITPOUT	Flag option for generation of APE output D-tape = 1 output on D-tape ≠ 1 do not create D-tape	I/ (N.D.)
LCHY.	Year of launch	I/ (year)
LCHMTH	Month of launch	I/ (month)
LCHDAY	Day of launch	I/ (day)
LCHHR	Hour of launch	I/ (hour)
LCHMIN	Minute of launch	I/ (minute)
LCHSEC	Second of launch	I/ (second)
MISSIONO	Mission number	Real/ (N.D.)
MODE	The mode indicator should be = 2.0 always for the Apollo mode; otherwise, APE will be terminated	Real/ (N.D.)

Table 4-4. Second Data Card Group (Continued)
(Namelist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
MTAPE	The star catalog input tape (usually = 27, as X-tape)	I/ (N.D.)
OPTANG	Window-mounted camera positioning angle between the negative camera Z-axis and its projection onto the X-Y plane measured positive toward the camera axis	Real/12.0(degree)
OPTDEL	Window-mounted camera positioning angle between spacecraft body X-axis and the projection of the negative camera Z-axis onto the body X-Y plane, measured positive toward the camera axis projection	Real/ (degree)
PHIIRS	The SIM-bay IR scanning radiometer center line roll position mounting angle, ϕ , as shown in Figure 2-2	Real, 37.75(degree)
PHIMAP	The SIM-bay mapping camera center line roll position mounting angle, ϕ , as shown in Figure 2-2	Real/ (degree)
RE	Conversion factor to convert Earth radii to km	d.p./6378.165D+0(km)
RFSMAT(1,1)... (3,3)	Transformation matrix from mean of NBY to the vehicle platform coordinate system	d.p./ (N.D.)
RHO	The SIM-bay mapping camera yaw positioning angle as shown in Figure 2-2	d.p./ (degree) (set 270.0 degree only for mapping and panoramic camera)
RMOON	Moon's local radius	' p./1736.1D+0(km)
SIGBET	Uncertainty in value of inner gimbal angle	Real/ (degree)

Table 4-4. Second Data Card Group (Continued)
(Namelist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
SIGBPR	Uncertainty in value of sextant camera shaft angle	Real/ (degree)
SIGDEL	Uncertainty in value of window-mounted camera positioning angle δ (OPTDEL)	Real/ (degree)
SIGGAM	Uncertainty in value of window-mounted camera positioning angle γ (OPTANG)	Real/ (degree)
SIGGPR	Uncertainty in value of sextant camera positioning angle γ' (SXLAMB)	Real/ (degree)
SIGINT	Uncertainty in value of stellar camera positioning yaw angle	Real/ (degree)
SIGPMP	Uncertainty in value of stellar camera positioning pitch angle	Real/ (degree)
SIGPSI	Uncertainty in value of outer gimbal angle	Real/ (degree)
SIGRHO	Uncertainty in value of camera alignment about the camera positioning roll angle	Real/ (degree)
SIGR1	Uncertainty in first REFSMMAT rotation, ρ_1 , about Y_{NBY}	Real/ (degree)
SIGR2	Uncertainty in secondary REFSMMAT rotation, ρ_2 , about intermediate Z-axis	Real/ (degree)
SIGR3	Uncertainty in tertiary REFSMMAT rotation, ρ_3 , about IMU X-axis	Real/ (degree)
SIGTAU	Uncertainty in camera shutter time	Real/ ()

Table 4-4. Second Data Card Group (Continued)
(Name!ist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
SIGTHE	Uncertainty in value of the middle gimbal angle	Real/ (degree)
SIGPR	Uncertainty in value of the sextant camera trunnion angle	Real/ (degree)
STPHR	Stop and start times for desired interval of state data from tape. Used only when state data are read from tape	I/ (hour)
STPMN		I/ (min)
STPSC		Real/ (sec)
STRTHR		I/ (hour)
STRTMN		I/ (min)
STRTSC		Real/ (sec)
SXLAMB	Sextant camera positioning angle between the sextant Z-axis and the spacecraft body Z-axis, measured positive from the body axis	Real/ (degree)
TAU	The excursion angle, τ , of panoramic camera	Real/ (degree)
TAUTME	The value of uncertainty in camera shutter time	Real/ (min)
TDATA(1,1)... (1,10)	The input flag, ITDAT;	Real/ (N.D.)
TDATA(2,1)... (2,10)	Second if ITDAT (=7 ATA (1,i) = 0.0, then low	Real/ (sec)
TDATA(3,1)... (3,10)	Minute bit rate; if ITDAT (=TDATA(1,i)) = 1.0,	Real/ (min)
TDATA(4,1)... (4,10)	Hour then high bit rate	Real/ (hour)
TMAX	The maximum time between adjacent time points for data interpolation	Real/ (min)

Table 4-4. Second Data Card Group (Continued)
(Namelist Input/INPUT1/)

The following 119 variables (TVs) in namelist/INPUT1/ are not used in APE and should be ignored.

TV in the namelist/INPUT1/	TV in the namelist/
ALPC	ORBIT
APL(1) and (2)	P1
APW(1) and (2)	P2
BRILL	P12
CAM(1),(2),(3),(4),(5),(6), and (7)	POELT
CAMA(3)	PHIC
CANQ(1) and (2)	PHIFHR
CC(1),(2),(3), and (4)	PHIFLR
CCC(1),(2),(3),(4),(5),(6),(7),(8), and (9)	PHIH
CONTRL(1),(2),(3),(4), and (5)	PHIHR
CTM	PHILR
D(1) and (2)	PSTGET(1),(2), and (3)
DELC	PTAPE
EPOCH(1),(2),(3),(4),(5), and (6)	P44
FCLHI	R12
FCLLO	RES
FLCA	SIGHS
FRAME1	STM
FRINC	TAPE
G	TGT
G1	TGT1,TGT2,TGT3,TGT4, and TGT5
IRU	THEFHR
ITRUN(1),(2),(3), and (4)	THEFLR
KINTPC	THEHR
KONFIX	THELR
KONST	THTC
KOPAN	THTH
MAN1,MAN2,MAN3,MAN4, and MAN5	THTHF
MI	THTHS
NOF	THTLF
NOP	THTLS
NPTS	TIME1(1)...(6)
	TIME2(1)...(6)

Table 4-5. Third Data Card Group For
SIM-Bay Mapping/Stellar Camera

Read in at sequences #385 and #543 with FORMAT #1787 for the SIM-bay mapping camera and at sequence #561 with FORMAT #1998 for the stellar camera.

Input Variable	Format	Columns	Description
IFRAME(1)	I4	1-4	Frame number
KZ	A1	5	Flag designation to skip the non-photo timing record in trajectory tape if KZ = "X"
IDAY	I2	8-9	Photo shutter time
IHR	I2	13-14	
IMIN	I2	18-19	
SECW	F2.0	23-24	
SECF	F3.3	26-28	Laser altimeter slant range in (meter)
RS	F6.0	32-37	

NOTE:

- (i) RS is not required.
- (ii) Extra cards containing "X" in column 5 have to be added to match every dummy, nonphoto timing record on the trajectory FORMAT3 tape. In this way the third data card group insures that the time tags of trajectory records and of the shutter times are matched.

Table 4-6. Fourth Data Card Group
(Namelist Input/INPUT2/)

Read in at sequence #424 if IFLAG = 0 or 2.

Input Variable	Type	Unit	Description
CSHAFT	Real	degree	β' - sextant shaft angle
CTRUN	Real	degree	θ - sextant trunnion angle
DVEL(1)	D.P.	E.R./min	\dot{X} - vehicle velocity component in selenographic coordinates
DVEL(2)	D.P.	E.R./min	\dot{Y} - vehicle velocity component in selenographic coordinates
DVEL(3)	D.P.	E.R./min	\dot{Z} - vehicle velocity component in selenographic coordinates
INNER	D.P.	degree	β - inner gimbal angle
MIDDLE	D.P.	degree	θ - middle gimbal angle
OUTER	D.P.	degree	ψ - outer gimbal angle
POS(1)	D.P.	E.R.	X - vehicle position component in selenographic coordinates
POS(2)	D.P.	E.R.	Y - vehicle position component in selenographic coordinates
POS(3)	D.P.	E.R.	Z - vehicle position component in selenographic coordinates
TGIMBL	D.P.	min.	Gimbal time from midnight day of launch

Table 4-7. Fifth Data Card Group - Panoramic Camera
Data Cards

Read in at Sequences #389 and #612 with FORMAT #1909 for the panoramic camera.

Input Variable	Format	Columns	Description
KOPAN	A1	1	The input direction designator = V for vertical positioned "mono" mode = F for forward positioned "stereo" mode = A for aft positioned "stereo" mode = X for skipping one trajectory record
IFRAME(1)	I4	2-5	Frame number (four digits)
IDAY	I2	6-7	} AET shutter time for panoramic camera
IHR	I2	9-10	
IMIN	I2	12-13	
FSEC	F6.3	15-20	

NOTE:

An extra card containing an "X" in column 2 must be input to match every dummy, nonphotographic timing record of the trajectory FORMAT3 tape. In this way the third data card group insures that the time tags of the trajectory records and of the panoramic camera shutter times are matched.

Table 4-8. Tape and Fastrand Unit Assignments

	Tape Unit		Tape Description	FORTRAN Tape Assign Statement (With R-Option)
	I/O Unit Designator	FORTRAN Unit Number		
Input Tapes	A	1	JPL19, Planetary Ephemeris tape (Fastrand)	7/8R ASG A=\$JPL19
	B	2	HOPE special trajectory FORMAT3 tape	7/8R ASG B=Tbbbb
	C	3	Gimbal data tape	7/8R ASG C=Tcccc
	X	MTAPE = 27	Apollo Photo Evaluation Star Catalog	7/8R ASG X=00158*
Output Tape	D	4	APE Output Tape	7/8RS ASG D=TSAVE
APE PCF Tape	Z	29	APE program PCF tape 1st file...relocatable only 2nd file...symbolic only	7/8R ASG Z=00157** 00163

*Available in the TRW ancient tape library.

**TRW00157 is used for CSM mounted cameras, the panoramic camera, and the lunar sounder. TRW00163 is used for the IR scanner. These tapes are available in the TRW ancient tape library.

4.1.2.2 Input Trajectory Data Tape

The APE input vehicle ephemeris data tape must be in the HOPE special trajectory format 3 specified below in Tables 4-9 through 4-11.

Table 4-9. Identification Record for the Format 3 Trajectory
and APE Output D-Tapes

Word	Type	APE Variable Name	Description
1-2	DP	HPETME(1)	Year (mod. 1900) } Month } Day } Base Time Hour } Minute } Second }
3-4	DP	HPETME(2)	
5-6	DP	HPETME(3)	
7-8	DP	HPETME(4)	
9-10	DP	HPETME(5)	
11-12	DP	HPETME(6)	
13-14	DP	DUM3(1)	Minutes from launch to the base time
15-16	DP	DUM3(2)	Right ascension of Greenwich, midnight day of launch (base time if GET = zero)
17-18	DP	DUM3(3)	Right ascension of Greenwich, midnight of base day
19-28	Ho1.	HPEHOL(1) ...(10)	Ten word BCD title (60 alphanumeric characters) read in on the title card of HOPE run
29	Ho1. (A6)	HPEHOL(11)	BCD program indicator: "HOPEbb" or "APEbbb"

Table 4-10. Data Records of Format 3 Trajectory Tape
(Units in e.r., minutes, and radian, except DUM82(44) = ω rad/sec.)

Identifier	Word	Type	APE Variable Name	Description
Time tag	1-2	DP	DUM82(1)	Time from base time, in minutes
Vector 1	3-8	DP	DUM82(2),(3), and (4)	Vehicle position vector, geocentric, MOF50
	9-14	DP	DUM82(5),(6), and (7)	Vehicle velocity vector, geocentric, MOF50
	15-20	DP	DUM82(8),(9), and (10)	Vehicle acceleration vector, geocentric, MOF50
Vector 2	21-26	DP	DUM82(11),(12), and (13)	Vehicle position vector, selenocentric, MOF50
	27-32	DP	DUM82(14),(15), and (16)	Vehicle velocity vector, selenocentric, MOF50
	33-38	DP	DUM82(17),(18), and (19)	Vehicle acceleration vector, selenocentric, MOF50
Vector 3	39-44	DP	DUM82(20),(21), and (22)	Vehicle position vector, selenographic
	45-50	DP	DUM82(23),(24), and (25)	Vehicle velocity vector, selenographic
	51-56	DP	DUM82(26),(27), and (28)	Vehicle acceleration vector, selenographic
Vector 4	57-74	DP	DUM82(29)...(37)	Vehicle P.V.A. vector, ECT(RTCC)
Sun Direction	75-80	DP	DUM82(38),(39), and (40)	Direction cosines of Sun, geocentric, MOF50
Sun Direction	81-86	DP	DUM82(41),(42), and (43)	Direction cosines of Sun, selenocentric, MOF50
ω	87-88	DP	DUM82(44)	IR scanning radiometer shaft rotation rate, ω in radian/sec only for the case of the nonstandard FORMAT3 trajectory tape; otherwise, zero
TV	89-138	DP	DUM82(45)...(69)	TV containing 0.00+0

Table 4-10. Data Records of Format 3 Trajectory Tape (Continued)

Identifier	Word	Type	APE Variable Name	Description
Sun Direction	139-144	DP	DUM82(70),(71), and (72)	Direction cosines of Sun, selenographic
T'	145-146	DP	DUM82(73)	TV (not used)
Vector 9	147-148	DP	DUM82(74)	Semi-major axis (a)
	149-150	DP	DUM82(75)	Eccentricity of orbit (e)
	151-152	DP	DUM82(76)	Inclination (i)
	153-154	DP	DUM82(77)	Longitude of ascending node (Ω)
	155-156	DP	DUM82(78)	Argument of perifocus (ω)
	157-158	DP	DUM82(79)	Eccentric anomaly (E)
	159-160	DP	DUM82(80)	Mean anomaly (M)
	161-162	DP	DUM82(81)	Latitude (ϕ)
	163-164	DP	DUM82(82)	Longitude (λ)
	165-206	DP	COVMAT(1)...(21)	Selenographic covariance matrix in lower triangular form
TV	207	Real	EOREOF	TV (not used)

Table 4-11. Terminator Record of the Format 3 Trajectory Tape

Identifier	Word	Type	APE Variable Name	Description
TV	1-164	DP	DUM82(1)...,(32)	TV (not used)
TV	165-206	DP	COVMAT(1)...,(21)	TV (not used)
Terminator	207	Real	"EOR" if additional cases follow "EOF" if this was last case	

4.1.2.3 Input Vehicle Attitude (Gimbal) Data Tape

The vehicle attitude data required for APE computations can be input by tape in either of the formats defined in Tables 4-12 and 4-13. Regardless of which format is used, the tape contents must be free of all anomalous data.

The Apollo Standard CSM Downlink Data Format

This, a "non-FORTRAN" data tape presents the data in 516 word physical records. There are no control words. Each physical record presents two sets of gimbal angles and a single data record time. The first gimbal angle set corresponds to a time .84 seconds prior to record time while the second set corresponds to a time .16 seconds after record time. The record format is defined in Table 4-12.

Apollo BMPROG Gimbal Angle Data Tape

The BMPROG gimbal angle data tape presents chronologically ordered CSM gimbal angle sets, each with a unique time tag. Each physical record contains 20 such data sets along with three command words. The 83 word BMPROG data record format is shown in Table 4-13.

Table 4-12. Pre-Apollo 15 (Downlink) Gimbal Tape Format

APE BUFF Address or Data Word	Type	Variable Name	Unit	Description
1-41	Real	None	-	41 TV (not used)
42	Real	CDUX=TGO(I)	Degree	Outer gimbal angle at time, TGOTME(I)
43	Real	CDUY=TGI(I)	Degree	Inner gimbal angle at time, TGITME(I)
44	Real	CDUZ=TGM(I)	Degree	Middle gimbal angle at time, TGMTME(I)
55-56	Real	None	-	56 TV (not used)
101	Real	CDUT=TRUN(I)	Degree	Sextant trunnion angle
102	Real	CDUS=SHAFT(I)	Degree	Sextant shaft angle
103-155	Real	None	-	53 TV (not used)
156	Real	THOW	Second	Record time
157-173	Real	None	-	17 TV (not used)
174	Real	CDUX=TGO(J)	Degree	Outer gimbal angle at time, TGOTME(J)
175	Real	CDUY=TGI(J)	Degree	Inner gimbal angle at time, TGOTME(J)
176	Real	CDUZ=TGM(J)	Degree	Middle gimbal angle at time, TGOTME(J)
177-212	Real	None	-	36 TV (not used)
213	Real	None (old TRUNK)	-	One TV (it is not used, but it was CDUT)
214-516	Real	None	-	303 TV (not used)

Table 4-13. Post-Apollo 14 (BMPPROG) Gimbal Tape Format

Data Word	Type	Variable Name	Unit	APE BUFF	Description
1	Real	Time #1	Second	BUFF(2)	Gimbal time #1
2	"	CDUX ₁	Degree	BUFF(3)	Gimbal angle, TGO at time #1
3	"	CDUY ₁	Degree	BUFF(4)	Gimbal angle, TGI at time #1
4	"	CDUZ ₁	Degree	BUFF(5)	Gimbal angle, IGM at time #1
5	Real	Time #2	Second	BUFF(6)	Gimbal time #2
6	"	CDUX ₂	Degree	BUFF(7)	Gimbal angle, TGO at time #2
7	"	CDUY ₂	Degree	BUFF(8)	Gimbal angle, TGI at time #2
8	"	CDUZ ₂	Degree	BUFF(9)	Gimbal angle, TGM at time #2
.					
.					
.					
77	"	Time #20	Second	BUFF(78)	Gimbal time #20
78	"	CDUX ₂₀	Degree	BUFF(79)	Gimbal angle, TGO at time #20
79	"	CDUY ₂₀	Degree	BUFF(80)	Gimbal angle, TGI at time #20
80	"	CDUZ ₂₀	Degree	BUFF(81)	Gimbal angle, TGM at time #20

4.1.2.4 Apollo Photo Evaluation Star Catalog

For the special "stellar camera" application, the input on unit X of the special "Apollo Photo Evaluation" star catalog tape is required. This catalog, a special arrangement of specific data extracted from the SAO star catalog tape, resides in the TRM ancient tape library (Tape 00158). Each physical data record contains fifty (50) 7-word logical records. The data record format is described below in Table 4-14.

Table 4-14. Apollo Photo Evaluation Star Catalog Format

Data Word	Type	Variable Name	Unit	Description
1	Real	A(1,1)	(N.D.)	SAO star number
2	Real	A(2,1)	(N.D.)	Magnitude of brightness
3	Real	A(3,1)	Degrees	SAO right ascension in the mean of 1950.0
4	Real	A(4,1)	Degrees/Yr.	SAO right ascension (MOF50) proper motion
5	Real	A(5,1)	Degrees	SAO declination in the mean of 1950.0
6	Real	A(6,1)	Degrees/Yr.	SAO declination (MOF50) proper motion
7	Real	A(6,1)	N.D.	Boss star number
8-14	Real	A(i,2), where i=1,...7		(the second set of the seven variables, the same as above)
15-21	Real	A(i,3), where i=1,...7		(the third set of the seven variables, the same as above)
22-343	Real	A(i,j), where i=1,...7; j=4,...19		(the 16 sets, from 4th to 19th, of the seven variables, the same as above)
344-350	Real	A(i,20), where i=1,...7		(the 20th set of seven variables, the same as above)

4.1.2.5 APE PCF Tapes

The APE PCF tapes, TRW00157 and TRW00163, are located in the TRW ancient tape library at TRW Systems Group, Houston Operations facility. The first file of these tapes contains all of the relocatable elements, while the second file contains all of the symbolic elements. TRW00157 is used for all CSM fixed-mounted cameras, the panoramic camera (with the alters defined in Appendix A.1), and the lunar sounder (with the alters defined in Appendix A.2). TRW00163 is used for IR scanner applications.

4.2 OUTPUT

For a general application, APE produces the standard on-line printouts and standard output D-tapes. The former are defined and described in Table 2-1, and the formats of the latter are described in Table 4-15. For a special application, APE produces various special output tapes. These are described in Tables 4-16 through 4-18.

The on-line printouts can be duplicated on the 4060 film by request. The additional three control cards, ∇ PLT, ∇ L FPR, and ∇ N FPR, are required for the film plotting.

For the stellar camera case (ISHFTR = 3), the special on-line plots are produced to simulate the star patterns. In the following two subsections, the tape outputs and the on-line outputs are described in detail.

4.2.1 Tape

For the general application, APE produces the standard output D-tape as specified in Table 4-15 if the input flag option, IPTOUT, is set to one (IPTOUT = 1).

For the special applications, APE produces the following special output tapes:

"IR Scanner Output Tape," Table 4-16

"Lunar Sounder Output Tape," Table 4-17

"Lunar Sounder Formatted Output Tape," Table 4-18

4.2.1.1 The Standard Output D-Tape

The general application of APE will produce the standard output D-tape if the input flag option, IPTOUT, is set to one (IPTOUT = 1). The standard

Table 4-15. Format of the Standard Output D-Tape

Data Word	Type	Variable Name	Unit	Description
1	Real	IGMT(1)	Year	Year (mod. 1900) } Base Time (GMT; Month Day Hour Minute Second
2	"	IGMT(2)	Month	
3	"	IGMT(3)	Day	
4	"	IGMT(4)	Hour	
5	"	IGMT(5)	Minute	
6	"	GMTSEC	Second	
7	Real	IDAY	Day	Elapsed time from launch (as defined by card inputs)
8	"	IMR	Hour	
9	"	IMIN	Minute	
10	"	FSEC	Second	
11-13	Real	GDB(1)...(3)	Km	Vehicle state vector, \dot{X} and \ddot{X} , in selenocentric mean of 1950.0
14-16	"	GDB(4)...(6)	Km/sec	
17-19	Real	X(1)...(3)	Km	Vehicle state vector, \dot{X} and \ddot{X} , in selenographic
20-22	"	X(4)...(6)	Km/sec	
23	Real	XLO	Degree	Longitude of vehicle nadir point
24	"	XLA	Degree	Latitude of vehicle nadir point
25	"	XLOC	Degree	Longitude of camera axis intersect
26	"	XLAC	Degree	Latitude of camera axis intersect
27	Real	P	Km	Vehicle radius
28	"	ALT	Km	Vehicle altitude
29	"	SFH	m/Km	Scale factor
30	"	VAZ	Degree	Azimuth of velocity vector
31	"	HDOT	Km/sec	Mean altitude rate
32	"	VTHETA	Km/sec	Horizontal velocity
33	"	AZM	Degree	Tilt azimuth
34	"	TILT	Degree	Tilt angle
35	Real	DUM18(12)	Degree	Sigma tilt azimuth
36	"	DUM18(10)	Degree	Sigma tilt angle
37	Real	SEA	Degree	Sun elevation at principal ground point
38	"	SAI	Degree	Sun azimuth at principal ground point
39	"	SSLN	Degree	Longitude of subsolar point
40	"	SSLT	Degree	Latitude of subsolar point
41	"	ALPHA	Degree	Alpha (see Table 2-1) angle
42	"	SWING	Degree	Swirl (see Table 2-1) angle
43	"	EPS	Degree	Emission angle

Table 4-15. Format of the Standard Output D-Tape (Continued)

Data Word	Real	Variable Name	Unit	Description
44	Real	DUM18(1)	Degree	Sigma swing angle
45	Real	PHASE	Degree	Phase angle
46	Real	DAN	Degree	North deviation angle
47	Real	PHI	Degree	PHI
48	Real	DUM30(4)	Degree	X-tilt angle
49	Real	DUM18(16)	Degree	Sigma PHI
50	Real	DUM18(13)	Degree	Sigma X-tilt
51	Real	KAPPA	Degree	KAPPA
52	Real	DUM30(5)	Degree	Y-tilt
53	Real	DUM18(17)	Degree	Sigma KAPPA
54	Real	DUM18(14)]	Degree	Sigma Y-tilt
55	Real	OMEGA	Degree	OMEGA
56	Real	DUM30(6)	Degree	Heading
57	Real	DUM18(18)	Degree	Sigma OMEGA
58	Real	DUM18(15)	Degree	Sigma heading
59	Real	ALTIM(1)	Km	Vehicle (laser) altitude
60	Real	ALTIM(2)	Km	Laser slant range
61-63	Real	COPT(1),(2),(3)	N.D.	Selenographic direction cosines of camera axes
64	Real	C	Km	Magnitude of vector from camera to principal ground point
65-73	Real	DUM30(19)...(27)	N.D.	Elements of the transformation matrix, SG2CM
74-82	Real	DUM30(10)...(18)	N.D.	Elements of the transformation matrix, LH2CAM
83-90	Real	PFOOT(1,1)...(8,1)	Degree	Photograph footprint (latitude and longitude of four corners)
91	Real	IRA(1) = IRAHRS	Hour	Right ascension of stellar photo center
92	Real	IRA(2) = IRAMIN	Min	
93	Real	RASEC	Sec	
94	Real	IDEC(1)	Degree	Declination of stellar photo center
95	Real	IDEC(2)	Min	
96	Real	DECSEC	Sec	

Table 4-16. Format of the Special Output D-Tape for the IR Scanner

Each physical record consists of a chronologically ordered set of nine of the below logical records.

Data Word Number	Type	APE Variable Name	Unit	Description
(Where $n = 0, 1, 2, \dots, 8$)				
1+28*n	Real	AET	Millisecond	Actual elapsed time
2+28*n	Real	X(1)	<div> <div>Km</div> <div>Km</div> <div>„</div> </div>	Vehicle state vector in selenographic
3+28*n	Real	X(2)		
4+28*n	Real	X(3)		
5+28*n	Real	XLO		Longitude of nadir point
6+28*n	Real	XLA		Latitude of nadir point
7+28*n	Real	XLOC		Longitude of IR scanner axis intersect
8+28*n	Real	XLAC		Latitude of IR scanner axis intersect
9+28*n	Real	ALT	Km	Vehicle altitude
10+28*n	Real	VAZ	Degree	Azimuth of velocity vector
11+28*n	Real	HDOT	Km/sec	Mean altitude rate
12+28*n	Real	VTHETA	Km/sec	Horizontal velocity
13+28*n	Real	AZM	Degree	Tilt azimuth
14+28*n	Real	TILT	Degree	Tilt angle
15+28*n	Real	SEA	Degree	Sun elevation angle at principal ground point
16+28*n	Real	KAPPA	Degree	<div> <div>KAPPA (see Table 2-1)</div> <div>PHI (see Table 2-1)</div> <div>OMEGA (see Table 2-1)</div> </div>
17+28*n	Real	PHI	Degree	
18+28*n	Real	OMEGA	Degree	
(19, 20, or 21)+28*n	Real	COPT(1),(2),(3)	N.D.	Selenographic direction cosines
22+28*n	Real	LATTIR	Millisecond	Limb crossing (trailing) time
23+28*n	Real	LA'LIR	Millisecond	Limb crossing (leading) time
24+28*n	Real	NU	Degree	Angular vehicle position
25+28*n	Real	DUM18(10)	Degree	Sigma tilt
26+28*n	Real	DUM18(16)	Degree	Sigma Phi
27+28*n	Real	DUM18(17)	Degree	Sigma Kappa
28+28*n	Real	DUM18(18)	Degree	Sigma Omega

Table 4-17. Lunar Sounder Special Unformatted Binary Output F-Tape

Data Word	Type	APE Variable Name	Unit	Description
1	Real	THR	Hour	} Time (GMT)
2	Real	TM	Minute	
3	Real	SEC	Second	
4-9	Real	GDB(1),(2), (3),(4),(5), (6)	Km,Km/ sec	Vehicle state vector, X and \dot{X} , in selenocentric, mean of 1950.0
10	Real	LONG	Degree	Longitude of nadir point
11	Real	LAT	Degree	Latitude of nadir point
12	Real	CDUX	Degree	Outer gimbal angle
13	Real	CDUY	Degree	Inner gimbal angle
14	Real	CDUZ	Degree	Middle gimbal angle

Table 4-18. Lurur Sounder Special Formatted Output E-Tape

This is an 800 bpi 9-track tape. The data for each APE computation point are written onto this tape with even parity as IBM BCDIC words into data record pairs. The formats of the two data records of each pair are as follows:

● First Record

Data Word Description	Data Time From Launch			Vehicle Position (X,Y,Z) Mean of 1950 (Km)	Vehicle Velocity ($\dot{X}, \dot{Y}, \dot{Z}$) Mean of 1950 (Km/sec)	Vehicle Nadir Point	
	Hr	Min	Sec			Long (Deg)	Lat (Deg)
Format	F5.0	F4.0	F6.3	3F13.7	3F11.7	F8.3	F7.3

● Second Record

Data Word Description	Data Time From Launch			Vehicle Gimbal Angles (ϕ_X, ϕ_Y, ϕ_Z) Outer, Middle, and Inner, Respectively (Deg)
	Hr	Min	Sec	
Format	F5.0	F4.0	F6.3	3F8.3

output D-tape consists of three parts which are the identification record, the data records, and the termination record. The identification record is the first record of the tape and is in the same format as the identification record for the HOPE special trajectory format 3 tape defined in Table 4-9. The terminator record is the last record of the standard tape and is in the same format as the terminator record for the HOPE special trajectory format 3 tape defined in Table 4-11. The data record consists of 96 single precision words and is defined in Table 4-15.

4.2.1.2 The Special Output D-Tape for Panoramic Camera

The output D-tapes produced from panoramic camera APE applications, by setting ITPOUT = 1, are only slightly different in content and format from those produced from generalized APE applications (Section 4.2.1.1). The title and terminating records are, as for the generalized application, identical with their HOPE special trajectory format 3 counterparts. For the panoramic camera applications, the first 90 words of the data records are defined in Table 4-15 and are identical with their generalized application counterparts. The remaining words are defined below.

<u>Data Words</u>	<u>Type</u>	<u>Variable Name</u>
91-98	Real	PFOOT(1,1)...(8,1). Inner photograph footprint (latitude and longitude of four corners)

4.2.1.3 The Special Output D-Tape for IR Scanner

The identification record is the first record of the tape, and the format is of the same format as that for the HOPE special trajectory format 3, identification record, which has been defined in Table 4-9.

The terminator record is the last record of the special tape and is of the format defined in Table 4-11.

Each data record consists of nine logical records of 28 single-precision words each. The contents of each logical record are defined in Table 4-10.

4.2.1.4 The Special Output F- and E-Tape for Lunar Sounder

The special application of APE, with the alter decks of Appendix A.2 for subroutines APECOM and EVAL, produce two special lunar sounder output tapes, F-tape and E-tape.

The special tape, F-tape, is an unformatted binary tape defined in Table 4-17.

The special tape, E-tape, is a formatted output tape defined in Table 4-18.

4.2.2 Listing

In this section, various on-line output examples are presented both for the general applications and the special applications of APE. The following is a list of these examples.

Figure 4-2 Nominal On-Line Output, General Application of APE for the SIM-Bay Mapping Camera

Figure 4-3 Special On-Line Output, Special Application of APE for the Stellar Camera

Figure 4-4 Special On-Line Output, Special Application of APE for the IR Scanner

Figure 4-5 Special On-Line Output, Special Application of APE for the Lunar Sounder

Figure 4-6 Nominal On-Line Output, General Application of APE for the Panoramic Camera

Figure 4-7 On-Line Printout of the Namelist Input Variables

Abstract

WAZ

Figure

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STATE VECTOR X (KM) 196.2236484 Y (KM) 191.2177250 Z (KM) -728.1301607

SELENOGRAPHIC -1481-505483 872.6949942 199.498035 DEG 199.498035 DEG 199.498035 DEG

LONGITUDE OF RADIR POINT 199.498035 DEG 199.498035 DEG 199.498035 DEG

LONG OF CAMERA AXIS INTERSECT 199.498035 DEG 199.498035 DEG 199.498035 DEG

SPALLCRAFT RADIUS 199.498035 DEG 199.498035 DEG 199.498035 DEG

SCALE FACTOR 199.498035 DEG 199.498035 DEG 199.498035 DEG

MEAN ALTITUDE RATE 199.498035 DEG 199.498035 DEG 199.498035 DEG

TILT AZIMUTH 199.498035 DEG 199.498035 DEG 199.498035 DEG

SUN ELEVATION AT PRIM GRND PNT 199.498035 DEG 199.498035 DEG 199.498035 DEG

LONGITUDE OF SUBSOLAR POINT 199.498035 DEG 199.498035 DEG 199.498035 DEG

ALPHA 199.498035 DEG 199.498035 DEG 199.498035 DEG

EMISSION ANGLE 199.498035 DEG 199.498035 DEG 199.498035 DEG

PHASE ANGLE 199.498035 DEG 199.498035 DEG 199.498035 DEG

SIGMA PHI 199.498035 DEG 199.498035 DEG 199.498035 DEG

KAPPA 199.498035 DEG 199.498035 DEG 199.498035 DEG

SIGMA KAPPA 199.498035 DEG 199.498035 DEG 199.498035 DEG

OMEGA 199.498035 DEG 199.498035 DEG 199.498035 DEG

SIGMA OMEGA 199.498035 DEG 199.498035 DEG 199.498035 DEG

SPACECRAFT ALTITUDE (LASER) 199.498035 DEG 199.498035 DEG 199.498035 DEG

SELENOGRAPHIC DIRECTION COSINES X 0.8192865 Y 0.4294904 Z 0.3798984

OF CAMERA AXIS

TRANSFORMATION MATRIX FROM SELENOCENTRIC TO CAMERA

24104772-01 -0.96113635+00 -0.27501958+00

-0.40318567+00 -0.24 791+00 -0.89243383+00

0.91980071+00 -0.12215483+00 -0.38167374+00

TRANSFORMATION MATRIX FROM LOCAL HORIZONTAL TO CAMERA

0.98750124+00 0.15058888+00 0.46520775+01

-0.15080805+00 0.98852220+00 -0.12342166+02

0.45920220+01 -0.82345487+02 0.99891860+00

PHOTOGRAPH FOOTPRINT

LATITUDE 199.498035 DEG

LONGITUDE 199.498035 DEG

DECLINATION 199.498035 DEG

DIRECTION TO STELLAR PHOTO CENTRE

RIGHT ASCENSION -1 HR, 37 MIN, 39.1 SEC

DECLINATION 50 DEG, 59 MIN, 19.7 -EC

Figure 4-2. Nominal On-Line Output, General Application of APE for the SIM-Bay Mapping Camera (continued)

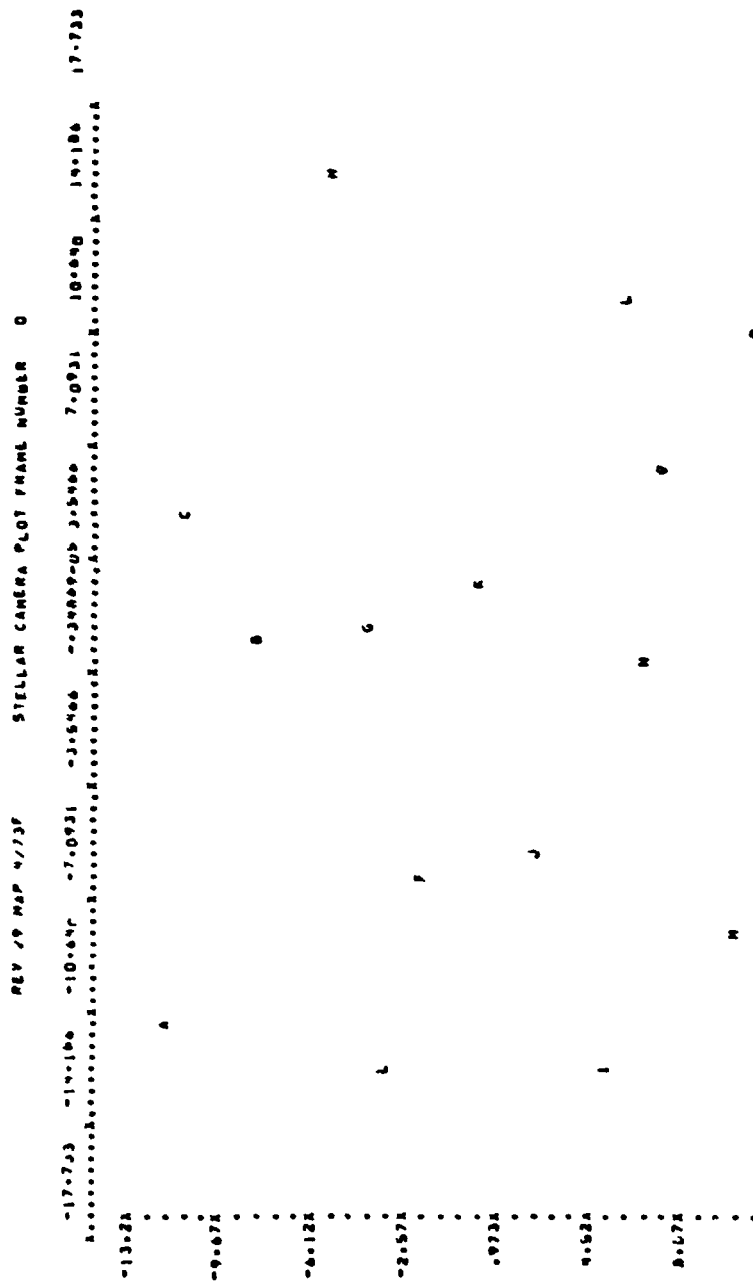


Figure 4-3. Special On-Line Output, Special Application of APE for the Stellar Camera (Continued)

STAR	Y DIAPOS	X DIAPUS	SAO NO.	HOSS NO.
A	-11.5461	-11.7277	18807.0	28304.0
B	-8.1351	-0.0964	19541.0	30302.0
C	-11.3225	3.9770	19827.0	30877.0
E	-3.1346	-13.3800	32627.0	28531.0
F	-2.1116	-7.3015	33078.0	29393.0
G	-3.6681	0.3620	33693.0	30440.0
H	-5.4829	14.5686	35147.0	32197.0
I	4.9866	11.3454	32809.0	28865.0
J	2.2570	-6.7061	33185.0	29608.0
K	0.3836	1.6122	33819.0	30627.0
L	5.8367	10.7066	34626.0	31586.0
M	9.8562	-9.1675	50456.0	29519.0
N	6.3308	-0.7985	33665.0	30391.0
O	7.0850	5.2570	34143.0	31046.0
P	11.1490	9.4762	52055.0	31426.0

Figure 4-3. Special On-Line Output, Special Application of APE for the Stellar Camera (Continued)

EXAMPLE OF IR SCANNER BY DATA AND ALTER DECK OF MC21UN=00123DATE 241073 PAGE 40

STATE VECTOR		YEAR		MONTH		DAY		HOUR		MINUTE		SECOND		Z	
1950.0	1950.0	1972	1972	12	12	14	14	14	14	14	14	14	14	14	14
STATE VECTOR	1950.0	1972	1972	12	12	14	14	14	14	14	14	14	14	14	14
SELENOGRAPHIC	1950.0	1972	1972	12	12	14	14	14	14	14	14	14	14	14	14
1950.0	1950.0	1972	1972	12	12	14	14	14	14	14	14	14	14	14	14
SELENOGRAPHIC	1950.0	1972	1972	12	12	14	14	14	14	14	14	14	14	14	14
1950.0	1950.0	1972	1972	12	12	14	14	14	14	14	14	14	14	14	14
SELENOGRAPHIC	1950.0	1972	1972	12	12	14	14	14	14	14	14	14	14	14	14
1950.0	1950.0	1972	1972	12	12	14	14	14	14	14	14	14	14	14	14
SELENOGRAPHIC	1950.0	1972	1972	12	12	14	14	14	14	14	14	14	14	14	14

Figure 4-4. Special On-Line Output, Special Application of APE for the IR Scanner

STATE VECTOR
1950.0 832.5501822 -1451.0830427 -784.9188972 -1.3009218 -1.9257439 2007 (KM/S) 2007 (KM/S)
SELENOGRAPHIC.....

LONGITUDE OF MADI POINT
GIMBALS 77.7354717 DEG LATITUDE OF MADI POINT -4.1990017 DEG

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STATE VECTOR
1950.0 799.4009947 -1474.1084444 -776.3445944 -1.3169795 -1.8979448 2007 (KM/S) 2007 (KM/S)
SELENOGRAPHIC 420.9541371 1703.5421156 -119.2501309 1.4702764 -1.3078521 -1.8979448 2007 (KM/S) 2007 (KM/S)

LONGITUDE OF MADI POINT
GIMBALS 76.5494614 DEG LATITUDE OF MADI POINT -3.4998748 DEG

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STATE VECTOR
1950.0 765.8307395 -1476.5741846 -767.9173821 -1.3323803 -1.8607207 2007 (KM/S) 2007 (KM/S)
SELENOGRAPHIC 466.2227735 1705.2626854 -183.1223902 1.4414939 -1.3323803 -1.8607207 2007 (KM/S) 2007 (KM/S)

LONGITUDE OF MADI POINT
GIMBALS 75.3640394 DEG LATITUDE OF MADI POINT -3.1000632 DEG

APOLLO 17 REV 74 MAP 4/737 PAGE - 54

STATE VECTOR
1950.0 731.9004547 -1510.1990999 -780.0232697 -1.3471116 -1.8300493 2007 (KM/S) 2007 (KM/S)
SELENOGRAPHIC 503.2343140 1776.0737007 -86.9534472 1.4518006 -1.3783090 -1.8300493 2007 (KM/S) 2007 (KM/S)

LONGITUDE OF MADI POINT
GIMBALS 74.1005744 DEG LATITUDE OF MADI POINT -2.4968354 DEG

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STATE VECTOR
1950.0 697.8995888 -1539.0790002 -796.3878113 -1.3611775 -1.8009779 2007 (KM/S) 2007 (KM/S)
SELENOGRAPHIC 570.011020 1766.0361460 -70.7338075 1.4415664 -1.4132631 -1.8009779 2007 (KM/S) 2007 (KM/S)

LONGITUDE OF MADI POINT
GIMBALS 72.9976286 DEG LATITUDE OF MADI POINT -2.1034822 DEG

Figure 4-5. Special On-Line Output, Special Application of APE for the Lunar Sounder

[illegible]

Figure 4-7. On-Line Printout of the NameList Input Variables

```

AP#      .00000000E+00.      .00000000E+00.
D        .00000000E+00.      .00000000E+00.
PHIM     .00000000E+00.      .00000000E+00.
THM      .00000000E+00.      .00000000E+00.
PHIC     .00000000E+02.      .00000000E+00.
THYC     .00000000E+00.      .00000000E+00.
PHILR    .00000000E+03.      .00000000E+00.
PHIMR    .00000000E+03.      .00000000E+00.
THELR    .00000000E+02.      .00000000E+00.
PHIFLR   .00000000E+02.      .00000000E+00.
FL        .00000000E+00.      .00000000E+00.
PHIFMR   .00000000E+02.      .00000000E+00.
THEFLM   .00000000E+02.      .00000000E+00.
THEFMR   .00000000E+02.      .00000000E+00.
PRINC    .00000000E+00.      .00000000E+00.
THMF     .00000000E+01.      .00000000E+00.
THMS     .00000000E+02.      .00000000E+00.
THLRF    .00000000E+02.      .00000000E+00.
THLS     .00000000E+02.      .00000000E+00.
FCLLO    .00000000E+01.      .00000000E+00.
FCLMI    .00000000E+00.      .00000000E+00.
PB        .00000000E+00.      .00000000E+00.
S         .00000000E+01.      .00000000E+00.
ALPC     .00000000E+02.      .00000000E+00.
DEL      .00000000E+02.      .00000000E+00.
NOP      .00000000E+00.      .00000000E+00.
MODE     .00000000E+01.      .00000000E+00.
ORBIT    .00000000E+02.      .00000000E+00.
RES      .00000000E+01.      .00000000E+00.
IRU      .00000000E+01.      .00000000E+00.
AOF      .00000000E+01.      .00000000E+00.
PI        .00000000E+00.      .00000000E+00.
FRAME1   .00000000E+01.      .00000000E+00.
EPOCH    .00000000E+00.      .00000000E+00.
TIME1     .00000000E+00.      .00000000E+00.
TIME2     .00000000E+00.      .00000000E+00.
AU        .00000000E+00.      .00000000E+00.
MISSMO   .00000000E+02.      .00000000E+00.
TAPE     .00000000E+01.      .00000000E+00.
PTAPE    .00000000E+00.      .00000000E+00.
NPTS     .00000000E+00.      .00000000E+00.

```

Figure 4-7. On-Line Printout of the Namelist Input Variables (Continued)

[illegible]

Figure 4-7. On-Line Printout of the Namelist Input Variables (Continued)

[illegible]

Figure 4-7. On-Line Printout of the Namelist Input Variables (Continued)

APPENDIX A

APPENDIX A

APE ALTER DECKS

Alter decks to Tape TRW00157 are required for the generation of support data for the panoramic camera and the lunar sounder. Sections A.1 and A.2 list the associated alters for each application.

A.1 APE ALTERS FOR THE PANORAMIC CAMERA

The required alters for the generation of panoramic camera support data are listed below.

```
' ASG Z=A04089
' SW ASG D=ASAVE
' ASG A=$JPL19
' XQT CUR
  TRW Z
  ERS
  IN Z
  IN Z
  TRI Z
' FOR,* EVAL,EVAL
-73,73
  DIMENSION TAPMAP(98)
-537,542
  TAPMAP(91)= PFOOT(1,2)
  TAPMAP(92)= PFOOT(2,2)
  TAPMAP(93)= PFOOT(3,2)
  TAPMAP(94)= PFOOT(4,2)
  TAPMAP(95)= PFOOT(5,2)
  TAPMAP(96)= PFOOT(6,2)
  TAPMAP(97)= PFOOT(7,2)
  TAPMAP(98)= PFOOT(8,2)
```

A.2 APE ALTERS FOR THE LUNAR SOUNDER

The required alters for the generation of lunar sounder support data are listed below.

```

* ASG Z=T00097
*SKFW ASG E=ASAVE
*SW ASG F=ASAVE1
* ASG A=$JPL19
* XGT CUR
  TRW Z
  ERS
  IN Z
  TRW Z
  TRI Z
IN FOR,* APECOM,APECOM
-23
  COMMED :GIMBAL/ GIMBAL(3)
-377
  GIMBAL(1)= GIMR(1)
  GIMBAL(2)= GIMR(2)
  GIMBAL(3)= GIMR(3)
-385,386
-406,407
-411,416
  GIMBAL(1)= 0.0
  GIMBAL(2)= 0.0
  GIMBAL(3)= 0.0
  LONG= DATAN2(PSG(2),PSG(1))/DTOR
  LAT= DATAN1(PSG(3)/DSQRT(PSG(1)**2+PSG(2)**2))/DTOR
  DYEAR= YEAR
  IF (MONTH.GT.6) DYEAR= DYEAR+1.000
  UJD1= 2433282.42335700+ 365.24219900*(DYEAR-1950.000)
  CALL ROTAT2(UJD1950,UJD1,15,DETUT,DUM82(11),DUM28(11),2)
  CALL ROTAT2(UJD1950,UJD1,15,DETUT,DUM82(14),DUM28(14),2)
  DUM28(20)= DUM82(20)* 1.0010
  DUM28(21)= DUM82(21)* 1.0010
  DUM28(22)= DUM82(22)* 1.0010
  DUM28(23)= DUM82(23)* 1.0010
  DUM28(24)= DUM82(24)* 1.0010
  DUM28(25)= DUM82(25)* 1.0010
-542,547
-1416,1419
  ENDFILE 7
  ENDFILE 6
  REWIND 7

```

```

      REWIND 8
      IN FOR,* EVAL,EVAL
-72      DIMENSION BUF1(8)
          COMMON /GIMBAL/ GIMPAL(3)
-97,98
-101,102
-106,106
-119,120
-122,264
-267,267
      1025 FORMAT(1H0,30X6HAPOLLO1XI2,3X4A6.5X7HPAGE - ,A1,1X,14)
-285,491
          WRITE (6,2043) GIMBAL
      2043 FORMAT (1H ,20X, 7HGIMBALS, 3F11.3)
          DO 10 K= 1,6
          BUF1(K)= GDB(K)
      10 CONTINUE
          BUF1(7)= LONG
          BUF1(8)= LAT
          NHR= GNTME/3600.000
          THR= NHR
          MIN= (GNTME-THR*3600.000)/60.000
          TM= MIN
          SEC= (GNTME-THR*3600.000-TM*60.000)
          WRITE (8)      THR,TM,SEC,BUF1,GIMBAL
          WRITE (7,100) THR,TM,SEC,BUF1
          WRITE (7,101) THR,TM,SEC,GIMBAL
          RETURN
      100 FORMAT (F5.0,F4.0,F6.3,3F13.7,3F11.7,F8.3,F7.3)
      101 FORMAT (F5.0,F4.0,F6.3,3F8.3)
      XQT T1

```


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3. "HOPE User's Manual," TRW Note No. 74-FMT-931, J. K. Daly, 25 January 1974.